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ASEPTIC TREATMENT OF WOUNDS

THE ASEPTIC TREATMENT OF WOUNDS

BY

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WITH A PREFACE BY PROF. BERGMANN

TRANSLATED FROM THE SECOND GERMAN EDITION
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AUTHOR'S PREFACE TO THE ENGLISH EDITION.

THE publication of an edition of his work in England is a matter of gratification to the author; England being the country where the great idea of the antiseptic treatment of wounds was first clearly conceived, and carried out in practice.

The present work is nothing more than an extension of that beneficent idea.

Originating in a clinique, the chief officer of which made the cultivation of this branch of the surgeon's art a special aim, the present work aims at faithfully representing the system, which has there been theoretically established and practically proved.

That this humble contribution may find favour and acceptance is the earnest hope of the author, and he returns hearty thanks to all who have kindly assisted in its publication in England.

DR. C. SCHIMMELBUSCH

November, 1894.

TRANSLATOR'S PREFACE.

Objection has been raised to the use of the term aseptic, as distinguished from antiseptic treatment; it being urged that in the one case heat is just as much an antiseptic as carbolic, or other chemical used in the other. But I think there is a distinction in the two practices which is fairly well indicated by the two words. In Aseptic surgery the great object aimed at is that everything which comes into contact with the wound shall be absolutely free from germs which are pathogenic for man or which are putrefactive, that is everything shall be aseptic as far as possible.

In Antiseptic surgery the wound was kept in an antiseptic state by irrigation or spray, so that germs getting into the wound might be killed or rendered innocuous. Everything coming in contact with the wound was either impregnated with an antiseptic, as dressings and sponges, or came straight from an antiseptic solution, as in the case of instruments and hands, that is everything was antiseptic.

Cheapness is a very great advantage of aseptic methods especially in Hospital practice. The following statement of the cost of apparatus, and articles required may be of interest.

The largest size of Lautenschläger's steam sterilizer (inside height $27\frac{3}{4}$ in., inside diameter $19\frac{1}{2}$ in.), with Schimmelbusch's boxes to fit, costs £16 5*s.*

Schimmelbusch's apparatus for the soda sterilization of instruments costs £10 5*s.*, but any tinsmith can make a boiler, trays, &c., which will answer all purposes.

The book muslin, which is used for sponges, cloths to shut off the peritoneal cavity, dressing, &c., costs from 3*s.* 9*d.*, 4*s.* 6*d.* to 5*s.* 3*d.* per piece of 40 metres (43·7 yards). The most inferior quality being used for sponges. Tricot, of which bandages are made, costs 12*s.* 3*d.* per piece of 40 metres.

The best moss, consisting of sphagna cymbifolia costs 100 M. per 100 kilo, about £5 per 220·5 lbs., in Germany. This grows abundantly in England, and could doubtless be obtained much cheaper should an English trade in it spring up. It only needs to be gathered, dried, picked over and then sterilized. As obtained in trade it is all ready for sterilization.

The preparation of all dressings, towels, sponges, &c., which were required for the operations was entrusted to

one sister, the "Theatre sister," at Breslau, where I saw the aseptic system carried out in its entirety, and had the opportunity of thoroughly studying it. Although Professor Mikulicz would sometimes be operating for more than four hours, there was never once any deficiency of supplies.

One difficulty in the efficient carrying out of aseptic methods in England is the frequent change of House Surgeons and Dressers. When the former only hold office for 6—12 months, and the latter for 3—6 months, they cannot get the same amount of practice and careful judgment as an assistant, who remains often for years under the same Chef in a German Clinic, and who has been gradually trained, first as a practicant, and then as a volunteer assistant, into the true spirit of asepticism.

The objections that the dressings are so large, and having no antiseptic impregnated in them allow the discharges to decompose easily, are of no practical weight whatever. For though bulky the moss is very light and not unpleasantly hot. Moreover, when the patient's skin has been carefully disinfected, the discharges dry so rapidly in the moss, that I never once saw any decomposition of the discharges.

I wish here to give my thanks to Mr. C. R. Hewitt

of the Royal College of Surgeons, for having kindly revised the Bibliography.

J. Beresford Leathes, Esq., has given me so much assistance, that I feel his name ought rightly to appear on the title page as a translator. Any merit which the translation may have is entirely due to his learning and courtesy.

ALFRED THEODORE RAKE.

October, 1894.

PREFACE TO THE SECOND EDITION.

THE short time which has elapsed since the appearance of the first edition has not brought with it any essential changes in the aseptic treatment of wounds.

The contents of this second edition are therefore pretty much the same as those of the first. Some novelties, especially in points of technique, have been introduced as far as space allowed.

Advice from various quarters, which friends have been good enough to offer, I have taken care to follow. For all such advice I take this opportunity of expressing my thanks.

DR. C. SCHIMMELBUSCH.

BERLIN. May 1st, 1893.

PREFACE TO THE FIRST EDITION.

During the tenth International Medical Congress, the undersigned exhibited in the Clinic the appliances for the sterilization of dressings, and entrusted his assistant surgeon, Dr. C. Schimmelbusch, with the demonstration of their efficacy against the micro-organisms which affect the course of healing and the treatment of wounds.

The blue colour, produced in the growth of the bacillus of blue pus, proved to the spectator the effects of the methods demonstrated, even without a microscope.

We were then asked, upon all sides, to collect together and describe what we had shewn.

This book is meant as an attempt to satisfy that wish. Scattered articles, published in Proceedings and Transactions by myself and my former and present assistants, Prof. von Bramann, Privat-docent Dr. Schlange, Dr. de Ruyter, and especially Dr. Schimmelbusch, have not been merely reproduced; they have been worked up and elaborated into a text-

book of the aseptic methods of wound treatment by my assistant, Dr. Schimmelbusch, who has been for years prominently engaged upon the subject in my Clinic.

However great has been the influence on surgical art of the transformation of antisepsis into asepsis, a concise exposition of the principles of the latter has so far been wanting. What Nussbaum's guide was for antisepsis, is still required for asepsis. To produce this the publisher has taken care to provide us with a good supply of old and new diagrams. We are pleased to have this opportunity of expressing our thanks to the capable and untiring octogenarian Mr. Ed. Aber.

I have felt almost daily in my demonstrations that my instructions upon the aseptic treatment of wounds were too short to meet the requirements of students. The clinical course is completely absorbed by our clinical material. Our audience, therefore, require a guide and a textbook to interpret and make them familiar with the details of the practice in the Clinic. This need Dr. Schimmelbusch has attempted to meet by this book. May it be useful to students no less than to practising surgeons.

ERNST VON BERGMANN.

BERLIN. Jan. 1st, 1893.

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CHAPTER I.

The Importance of the Aseptic Treatment of Wounds.

A comparison of the results of modern surgery with those of the past—Rapid healing—The fear of predisposition to inflammation, or of the patient's age, is a thing of the past—The extension of the domain of surgery—Recognition of the causes of the infection of wounds—Lister.

It is well for us, who have profited by the achievements of our predecessors, and who watch the progress of science perhaps not without occasional misgivings, to look back upon the past and gauge the value of what we have inherited. We need not go back to ancient times, in which the performances of surgery were cramped by want of anatomical and physiological knowledge, no less than by imperfect technique; we need go no further back than thirty or forty years. Let us compare the modern epoch of our science with that period, in which the highest abilities and a degree of operative skill, that we cannot hope to surpass, were powerless to control the dark issues of the fate that hovered over the wounded, making all calculations of the results of operations futile. At that time, the idea of a wound was inseparable from that of fever; the healing of a wound without inflammation was not

known, and wound fever and wound inflammation appeared to be the normal reaction of the injured organism. It was then that Pirogoff wrote his treatise on luck in surgery, in which, after long years of surgical practice, he so resignedly gave expression to the feeling of the futility of his own skill, and estimated the influence of the surgeon, of the method of treatment, and of mechanical dexterity, at nothing as compared with that of chance in determining the success of an operation. Suppuration, purulent œdema, hospital gangrene, erysipelas, and traumatic tetanus, the scourges of surgery, as Pirogoff aptly terms them, dogged the steps of the surgeon and frustrated his success.

Lindpaintner writes of Nussbaum's Clinic in Munich as follows:—"Eighty per cent. of all wounds were attacked by hospital gangrene. Erysipelas was so much in the order of events, that its occurrence could almost be regarded as normal; it was a standing axiom to sew up no scalp wound; healing by primary intention was practically unknown, and suturing had at most the result of favouring by retention of secretion, the occurrence of erysipelas. In one year 11 out of 17 amputations died of pyæmia alone; in our department a compound fracture was very rarely to be seen, for either the limb was amputated at once, or the occurrence, in a few days' time, of purulent infection, hospital gangrene and septicæmia rapidly led to a fatal result." The mortality after compound fracture, in Volkmann's Clinic at Halle, had been 40 per cent. during the long period of his predecessor's rule as well as during his own, and in the years 1871 and 1872 the number of the victims claimed by pyæmia and erysipelas was so large, that Volkmann entertained the idea of closing his Clinic for a time.

How different is all this at the present time! The

Clinics, in which twenty years ago hospital gangrene was reckoned the most frequent disease of wounds, are now-a-days in such a condition, that the medical student no longer has the opportunity of seeing hospital gangrene, and most young surgeons no longer recognise the disease. The most serious operations under modern surgeons run a favourable course with such a certainty, that the chance of a failure in the healing hardly enters into their calculations. Fatal inflammation after amputation should, as a rule, no longer occur.

There is now no such thing as good and bad luck in the treatment of a wound; the fate of the patient lies in the hands of the surgeon who performs the operation and dresses the wound. The old saying of Ambroise Paré, "Je le pansays, Dieu le guarit," has ceased to be the involuntary motto on the shield of the operating surgeon, and in putting on the dressing, the surgeon undertakes the entire responsibility for complete and certain healing. "A short time ago," says Volkmann in his excellent way of expressing it, "the surgeon, when he had completed a bloody operation, according to rule, was like a husbandman, who having sown his field, waits with resignation for what the harvest may bring, and reaps it, fully conscious of his own impotence against the elemental powers, which may pour down on him rain, hurricane, and hailstorm. Now he is a craftsmen from whom one expects good workmanship."

In the duration of the processes of healing, modern surgery has been revolutionized. In 1875 Nussbaum complains that accident cases from the working classes were only provided for, according to contract, for 9 weeks in hospital, and adds that for many this limit was not sufficient, that even in the case of quite in-

significant wounds, healing was not complete till much later, owing to inflammation. The healing of an amputation of the breast usually took from three to six months, the healing of the major amputations often several months. Now we see amputations of the breast, with clearing out of the axilla, get well in a fortnight, and complain, if in a case of amputation of the thigh we have to keep the patient in the hospital over the third week, in order to have the artificial limb adapted. Our ideas are entirely changed. We no longer believe that the healing of a fresh wound must be different in the case of a cancerous or tuberculous patient from what it is in a sound one. The spectre of diathesis to wound inflammation has disappeared. We operate, with the assurance of uninterrupted healing, on the youngest and oldest no less than the fully developed adult. The modern surgeon no longer anxiously avoids injury to the joints and body cavities, but without hesitation opens the abdomen or the skull, and touches organs which to the ancients were a *noli me tangere*.

For this entire transformation in our art of healing, we have to thank the great discoveries, which at one stroke have dispersed the darkness which has hung for thousands of years over the infection of wounds. These discoveries have shown us, that like putrefaction and fermentation, wound infection depends upon minute organisms, and that it is only necessary to prevent their access in order to do away with the infection of a wound.

And although the weapons, which we to-day use against the now recognised foe, are no longer those which were first chosen, and although yet better be discovered in the future, our gratitude will always remain the same to him who first showed us the path along which we progress, and the name of Lister will always be illuminated with the brightest light.

CHAPTER II.

Infection by the Air and by Contact.

The idea of the conveyance of disease by the air is very old—John Hunter's doctrines—Subcutaneous operations—Lister's treatment was originally directed against infection by the air—Organic matter, and not the air, is the proper abode of micro-organisms—Germs are present in the air only as dry dust—No bacteria are given off from damp surfaces—Human breath is always free from germs—In the air far fewer germs are present than in organic matter—Pathogenic germs are found in the air only in small numbers—Infection from the air is therefore less to be feared than infection by contact—Practical experience has proved the harmlessness of air free from dust upon wounds—No special precautions are necessary against infection from the air, if only great clouds of dust are not stirred up—Contact infection deserves minute attention.

The belief in the dissemination of disease by means of the air is very old, at any rate older than scientific medicine. For a long time the idea was dominant in surgery, that diseases of wounds were caused through the air, and this belief was canonized when John Hunter attributed the fact that subcutaneous wounds such as simple fractures always ran their course without fever and suppuration, to the non-access of air to the injured part. If the hospital patients of a surgeon, in the past, were all attacked by gangrene and putrefaction, it was always the air of the ward which was thought to have infected them, and to be the cause of all the evil. The surgery which recommended the so-called subcutaneous operations, the introduction of instruments through the smallest possible punctures, in order to cut through

tendons and saw through bones, groping about deeply and in the dark, was nothing but an endeavour to copy Nature in her subcutaneous injuries, and to make wounds to which the air had no access. It was against the air that Lister directed his first endeavours in antisepsis; not against the air as a gas, but against the putrefactive germs suspended in it, which he presumed set up putrefaction in the secretions and in the wounds, just as they cause all decomposition and putrefaction in organic matter. "The frequency of disastrous consequences in compound fracture," thus Lister begins his first communication to the *Lancet*, May 16th, 1867, on a new method of treating compound fracture, abscess, &c., "contrasted with the complete immunity from danger to life or limb in simple fracture, is one of the most striking as well as melancholy facts in surgical practice. If we inquire how it is that an external wound communicating with the seat of fracture leads to such grave results, we cannot but conclude that it is by inducing, through access of the atmosphere, decomposition of the blood which is effused in greater or less amount around the fragments and among the interstices of the tissues, and, losing by putrefaction its natural bland character, and assuming the properties of an acrid irritant, occasions local and general disturbance."

And as the investigations of Pasteur, Schwann, von Dusch and others had shown how organic matter, blood and animal tissues could be protected from putrefaction, by keeping it free from living germs, so Lister in his new treatment sought to keep away the putrefactive germs from his wounds. To destroy the germs imported by the air, he washed his wounds with carbolic acid, the antiputrefactive efficacy of which he had first

learnt to his surprise, in the deodorisation of the sewage fields of Carlisle. He then laid upon the wound the dressing, which was also soaked in carbolic acid; this was covered with a layer of impermeable material and the whole wound most carefully bandaged up, so that by exclusion of the air no germ could reach the wound.

Subsequently he used during the operation and the change of dressings, the carbolic spray producer, which during its action shed a fine mist of carbolic acid over the whole region of the wound, and thus placed the wound in an atmosphere, which should be free from fatal germs of all sorts.

At this time when Lister made his first practical experiments with his new treatment, our knowledge of the germs in the air was very limited. That they were alive and extremely minute was certainly proved, but of their number, shape and conditions of life hardly anything was known. Tyndall had shown that they were present in the motes, which are visible when a beam of light falls through an opening in the closed shutters of a dark room; Pasteur had drawn air through gun-cotton, so as to filter off the germs, and after dissolving the gun-cotton in ether had microscopically examined them, and Pouchet had caught the particles of dust on a damp glass plate, against which he blew the air. But all these investigations had on the whole advanced us but little. That we have now, after a relatively short time, obtained a fairly detailed knowledge of the number, shape and conditions of life of these germs of the air, and that our ideas about them have become in a sense conclusive, we owe to the remarkable perfection of the methods of bacteriological investigation; and for this a tribute of thanks is due in the first place to Robert Koch.

If we look through the latest researches upon the germs in the air, it is satisfactory to find a remarkable agreement in their results, and the more so because the methods of different experimenters have differed from one another in many matters of detail.

Almost all the germs included under the general name of micro-organisms, occur in very changing proportions in the air; baccilli, cocci, yeast and mould fungi are usually present at the same time. But there are great variations in the proportional numbers of the different germs, although these variations are determined by certain definite conditions. For example, in dwellings fission fungi, bacilli, and cocci are present in overwhelming numbers as compared with mould fungi, whilst in the open air more mould spores are found. The number of germs varies between a score or so and many thousands per cubic metre.

The air of great cities is richer in germs than that of the country; in damp weather the number of germs is usually smaller than in dry; when there is a wind it is greater than when the air is still; in the middle of the Atlantic Ocean and on the Alps, in the region of eternal snow, the air is practically free from germs. Wind off the land is usually richer in germs than wind off the sea; for example, Condorelli-Mangeri has proved that the wind which blows from the land towards Catania has always more air germs than that which blows from the Mediterranean. Uffelmann found the same relation for the land and sea winds at Rostock and Giorgio Roster on the Island of Elba.

Many of the early authorities, for example Leuwenhoeck, thought that all germs arose from the air, and that it was by germs imported by the air that organic matter was decomposed. The same view is

very plainly seen in the first essays of Lister. This tendency to regard the air as the principal source of the lower fungi, and therefore as the main agent in the infection of organic matter, our present knowledge of the conditions of bacterial life has made it necessary to break with once and for all. It is not the air, which in the first instance hatches and harbours the fatal germs, and then infects everything else; the very reverse of this rather holds good. In organic matter the microbes thrive, and from it only occasionally pass into the air. The circumstances that favour the propagation of micro-organisms, namely warmth, moisture, and a free supply of food, are not to be found in the air; the air is anything but a favourable dwelling place for fission, yeast and mould fungi; on the other hand there are germs, for whose growth the air as a mixture of gases is directly injurious, the so-called anaerobic fungi, among which are included the active agents of traumatic tetanus: and many properties of the air especially in the open, such as dryness, the diffusion of daylight and the radiation of light from the sun, we now know to exert an unfavourable and even destructive influence upon the lower fungi. The air is only a temporary halting place into which micro-organisms may stray away from their proper element, the moist, warm, organic matter of the earth's surface, and that only when a breath of air carries them away as dry particles of dust. Nægeli, twenty years ago, experimentally proved his theory, that the lower germs can only be mixed with the air as dry dust, and that they never pass into the air from fluids rich in organisms. Many, even now, when they smell the disagreeable odours of a decomposing fluid, find it difficult to rid themselves of the idea, that germs are being given off with the

vapours, and yet all the researches directed upon this point have shown it to be untenable. The evil smelling air contains much fewer germs than that which we breathe in as pure and pleasant, and the stinking atmosphere of water closets, sinks and sewers is uniformly found to be purer bacteriologically than the air of streets, dwellings or gardens.

According to the investigations of Hesse and Petri the free air in the middle of Berlin always contains from several hundred to over a thousand fission fungi per cubic metre, and that of dwelling rooms from six thousand to ten thousand; whilst according to Petri the air in the sewer under the Potsdam Square contains no germs at all or only a few solitary ones. It is there, as a matter of fact, that the purest air in the whole of Berlin, from a bacteriological point of view, is to be found; and even if you climb to the top of the Rathhaus tower, you would still breathe in more bacteria; for even there, according to Hesse, 800 fungi are found in a cubic metre.

It has been experimentally proved that even strong draughts are not able to carry away germs with them from the surface of fluids containing germs, unless the draught blows the fluid into a spray, and so scatters them broadcast. The sun, when it burns down on water swarming with micro-organisms, will certainly vaporize the water, and make it give off a bad smell, but it will never free the organisms from the fluid; and if bacteria, as was shown by Foutin after a storm in St. Petersburg, are to be found in drops of rain and hailstones, it must not be supposed that these germs were originally exhaled with the vapour from the water upon the earth's surface, but that the precipitated drops of water subsequently enclosed the particles of dust in the atmosphere.

The reason why dry and moving air is richer in germs is because it contains more dust and this is more scattered. The reason why after rain the air is not so rich in germs is because firstly the bacteria are carried down by the falling drops, and secondly the rain moistens the surface of the earth and for the time lays the dust. And if on the other hand the air over high glaciers and in mid-ocean is always free from germs, this can only be due to the fact that there no dry particles of dust can be blown up by movements of the air, and that the ice of the glacicr and the sea watei keep a secure hold upon the germs that they contain. Condorelli-Mangeri found that after the crowded fairs had been held at Catania, the air was richer in germs than it was before. The air of hutches, in which many small animals are kept for experimental purposes, is, according to Petri, very rich in germs, containing as many as 34,000 fission fungi and 7,400 mould fungi per cubic metre. The number of bacteria in the air of a factory rises immediately work is begun, and it is always greater in barracks, wards and dwellings shortly after cleansing, sweeping and dusting. In Billroth's operating theatre, the number of bacteria in the air is greatest after the students have left it, and in a schoolroom, according to Hesse, it rises during school hours from 3,000 to 20,000 per cubic metre, and whilst the children are leaving to 40,000. Detailed analyses of the air at different times of the day in von Bergmann's Clinic, showed that the number of bacteria was always greatest after the morning cleaning, and gradually sank towards night (Schimmelbusch and Cleves-Symmes). All these results only illustrate the effect of the stirring up of dry dust on the number of the bacteria in the air.

There is among doctors as well as among the laity,

a widely prevalent belief that expired air is poisonous, and the fables which formerly endowed monsters with a poisonous breath that destroyed everything that it encountered, is a striking expression of this belief. It is remarkable that in the early days of antisepsis little importance was attached to the effect of expired air upon wounds, for it might have been expected that the prevalent views upon this point would have given rise to much uneasiness in the mind of an operator.

This uneasiness has been dispelled by exact bacteriological investigation. The contamination of the air of a crowded room is a process in which micro-organisms, fission- and mould-fungi play no part, and is due rather, like the foul air in sewers, to the presence of gases. Since Tyndall proved that expired air is free from germs, many investigations have been undertaken and these have unanimously resulted in showing that, instead of fission fungi being given off from the respiratory tract, they are taken up and to a certain extent filtered off by it. According to Strauss, out of 600 fungi inspired from the air of a ward rich in germs, not more than one was found in the expired air. Although Cadéac and Malet made sheep, suffering from anthrax and sheep-pox, breathe upon healthy animals through a tube ·30 to 1·50 metres long, varying their experiments in many ways, yet they never succeeded in infecting a sound animal from a diseased one by means of the expired air. The lungs give off no germs at all from their moist surfaces; they act rather as a filter, and the expired air could only become a vehicle for germs if sputum, mucous secretion, or even particles of tissue were coughed out with it. The number of bacteria in a crowded room is, as Strauss insists, diminished by the act of respiration; and a surgeon

who operates in a theatre thronged with students stirring up dust, may derive consolation from the reflection that every student with each breath renders some 500 cubic centimetres of air free from germs. The surgeon need have no fear of infecting a wound by his breath, nor of a septic patient's breath filling the ward with infectious germs.

Every advance in bacteriological science, each fresh inquiry into the habitat of fission fungi and the modes of infection of wounds, has set the fear of infection by the air further from our thoughts and brought that of direct contact with organic matter into greater prominence. The simple estimation of the number of germs that can gain access to a wound from the air, as compared with the number conveyed by contact, disposes effectually of any fear of infection through the air. The statement that a cubic metre of air contains one, ten or forty thousand micro-organisms sounds formidable no doubt, but what are these numbers compared with the number of bacteria in decomposed organic matter? The water of the Spree at Berlin, for example, contains in a cubic centimetre, that is in a millionth part of the above quantity of air, many thousands and usually many hundred thousands of fission fungi, and the number of bacteria in a drop of pus or other highly decomposed fluid is reckoned in millions. Let us take a practical illustration of this point. The germs in air, which is fairly free from currents, fall by gravity to the ground or upon a wound. We have determined by many experiments in von Bergmann's Clinic, that the number of germs which are deposited on a square decimetre, in the operating theatre when the students are there, in the course of half an hour, is between 60 and 70; the number thus deposited from the open air in the

neighbourhood of the Clinic varies, but is usually much less. The Spree flows past the Clinic, and at this place, according to the investigations carried out by the hygienic institute, the number of germs in its water varies from 3,000 to 154,000 per cubic centimetre; on the average 37,525. To take a common instance: a boatman on the Spree gets a wound, measuring we will say a square decimetre. He comes to the Clinic with his wound open and uncovered, and has it dressed half an hour after it was inflicted. At most 60 or 70 germs will have alighted upon his wound, and these having fallen lightly on it will be quite superficially situated on the blood clot. But should the same man irrigate his wound slowly and thoroughly with a litre of Spree water, which by the way is the usually recommended process of cleansing a wound, it is obvious that more than 37,000,000 fission fungi have been brought into contact with it; and if he binds round it a dirty cloth, with the usual amount of decomposing organic matter rich in bacteria upon it, the number of germs introduced would probably be difficult to express in a merely decimal system of notation.

Lister started with the idea that the fungi in the air which are the cause of putrefaction and decomposition in organic media, were also that of infection of wounds. Later investigations have long since proved the falsity of this assumption and have shown that the germs of wound infection are, generally speaking, quite different from those of ordinary putrefaction. The search for the micro-organisms, which we now know to be the active agents in wound infection, in the air, has given almost or even entirely negative results. Far and away the greater number of the aerial bacteria belong to innocuous mould-, yeast- and fission-fungi, which are not

pathogenic for man. When germs of wound infection have been found in the atmosphere, as, for example, in the air of hospitals, these have been in a very small minority compared with other fungi; and it appears from the latest reports that while the air is an uncongenial resting place for any bacteria, it is particularly so for the germs of wound infection; and that those which unavoidably get into it quickly perish.

One after the other these common fallacies have yielded before exact investigation, and little, in fact almost nothing, remains of Lister's original views on the significance of the germs in the air in the infection of wounds. The fate of his views in the ordeal of practical experience has been that of other brilliant ideas; that which was true in them has crystallized out from the irrelevant and accidental, unaffected by the accessories with which it was introduced. Experience, confirmed by bacteriological experiments, taught practical surgeons to attach less importance every year to the risk of infection by the air and to lay greater stress on the dangers of contact. First one operator and then another timidly left off the carbolic spray, and then the spray quickly disappeared everywhere, because experience plainly and clearly showed its superfluity. And the same fate awaits the irrigation of wounds with antiseptics, a practice recommended by Lister in all cases, as a prophylactic against such germs as might happen to reach a wound from the air. Many operators were energetic in the practice of irrigation to justify the omission of the spray. But a clear proof that antiseptic irrigation is erroneous and has no place in the enlightened treatment of wounds, is afforded by the results obtained years ago by von Bergmann and other operators stimulated by his example. It is not neces-

sary either to fill the air of our operating rooms with carbolic spray, or to introduce filtered and cooled air through ventilators, or to pour over our operation wounds streams of any antiseptic agent; we can obtain faultless results without all this. The only operating theatre in von Bergmann's Clinic is a many-cornered room, and has an amphitheatre built of wood, which is filled at every clinical demonstration with several hundreds of spectators. Large curtains, hanging down from the roof, keep off the sun on one side; an arabesque lattice-work covers a part of the back wall of the theatre, and close over the head of the operator on ornamental pedestals are placed the busts of the three great predecessors of von Bergmann. And though no one pretends that these conditions are unfavourable to the collection of dust, indeed repeated experiments have shown that there are more bacteria here than in any room in the Clinic, yet all operation wounds run as favourable a course as one could possibly wish. The peritoneal cavity is unhesitatingly opened in this air; great operation wounds are made; during an operation a pause is made to openly and freely demonstrate the wound to the students, and this is then simply sewn up; but yet no case has occurred in which any harm has been seen to result from the wound remaining exposed to the air.

The only thing that must be done in order to avoid a possible infection by the air, is to guard against immoderate stirring up of dust. Operations should not be performed where freely moving air stirs up clouds of dust and dirt that might be deposited on the field of operation. In a closed operating theatre there is no difficulty in avoiding this; in field surgery the case is different. Cleaning and sweeping should not be al-

lowed just before an important operation, for as we have seen this always stirs up dust. Especial care must be taken that dry dressings filled with pus are cautiously dealt with.

That the spray does not exert the favourable influence on the air that Lister ascribed to it has been conclusively proved; according to the investigations of Stern its purifying powers are quite insignificant. It is equally futile to attempt to make an impression on the number of bacteria in the air of a room by means of ventilation and currents of air. The quickest and most certain way of effecting this object is, according to numerous investigations, to allow the germs to settle. Stern's experiments show that an hour and a half after the air of a room has been impregnated with bacteria by the raising of clouds of dust, the heavier particles will have settled to the ground and the air be practically clear; the lighter particles such as wool and cotton fibre, and the spores of fungi require a rather longer time. The best means therefore to render the air of an operating room free from germs, is to keep the room shut for several hours till all the germs have sunk to the ground.

But in doing this, everything that is necessary for preventing the infection of a wound by the air, has been done; for the rest our attention must be directed to the avoidance of infection by contact.

CHAPTER III.

The Material Causes of Wound Infection.

The diseases of wounds have a purely local origin, and are due to bacteria, altogether foreign to the healthy body, being inoculated from outside—The argument from simple fractures—Traumatic erysipelas, its cause and mode of origin—Traumatic tetanus—The bacteria concerned in the formation of pus—Other germs of disease—There is no such thing as progressive suppuration without micro-organisms—All the problems of wound infection are not yet solved—Our first duty is to ward off the germs of infection.

The assumption that most of the infectious diseases of wounds were the manifestation of a disordered constitution, and did not arise in and spread from the wound, was long the source of much error and mistaken treatment in surgery, even down to recent times. Even after the discovery of the relation of bacteria to disease, it was a long while before the new doctrine took a firm hold on surgical practice. Many surgeons, without questioning the significance of bacteria, were content to rehabilitate the old ideas, and assumed that the germs were always circulating even in healthy blood, and that the injury merely gave them the opportunity to develope and give trouble. This assumption was rooted in mistakes. The germs which early investigators detected in all the tissues of the body were nothing but granular detritus and degenerated nuclei. With the improvement of bacteriological methods, there was no difficulty in obtaining healthy blood and fragments of healthy tissues, and in finally establishing,

with proper precautions against decomposition, their absolute freedom from bacteria. But long before this, the course taken by subcutaneous injuries should have convinced the experienced practitioner of the same fact. Indeed, the fact that simple fractures always heal without fever or suppuration is the strongest proof that the source of mischief, when a wound does go wrong, is not within the body as was recognised long ago by John Hunter.

In the case of erysipelas, for instance, these points have been thoroughly established. Fehleisen has demonstrated the cause of the disease, cultivated it

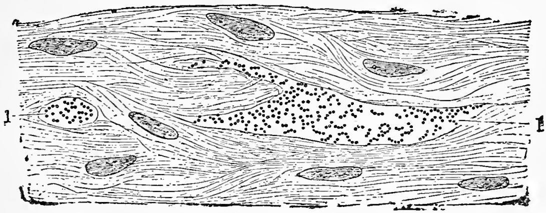

FIG. 1.—Streptococci of erysipelas in the skin after Robert Koch.

on artificial nutrient media, and definitely ascertained its etiological *rôle* by means of inoculation on animals and man. According to Fehleisen's experiments, the cause of erysipelas is a coccus, which as it grows arranges itself in rows, and so is called a streptococcus. If this streptococcus attacks a skin wound, it penetrates into the lymph channels of the skin, and there multiplies with great rapidity and the most extraordinary activity. In skin attacked by erysipelas, all the spaces are closely packed with organisms, as is shown in fig. 1.

As the streptococci push themselves further into the lymph channels, new areas of the skin are involved.

The well known symptoms of violent inflammation are a marked feature in the clinical aspect of this affection and occur wherever the germs lie in the skin. Hyperæmia is manifested by the intense redness of the skin, whilst the exudation of fluids is conspicuous in the swelling and occasional formation of blebs; and at the same time an extensive migration of colourless blood corpuscles takes place. The process advances till sooner or later it is arrested from causes concerning which we are as yet completely in the dark; the organisms die off and disappear, together with all signs of inflammation, and usually in a short time the skin regains its normal appearance.

The most abundant and powerful streptococci are always to be found at the edge of the diseased surface, and from such a part there is no difficulty in obtaining a cultivation of the organisms. All that is necessary is to cut out a very small piece of the affected skin with a pair of scissors, put it on to a solid artificial medium made from bouillon, and then the growth of the fungus can very soon be seen to spread to neighbouring parts in the form of small white colonies. If a stab culture is made in nutrient jelly in a test-tube, by means of a sterilised and then infected platinum wire, in a few days little rounded colonies will appear all along the stab. The most suitable temperature for the growth of the streptococci is that of the body, so that they thrive best in an incubator kept at 37° C. They grow on many artificial nutrient media, and many investigators have succeeded in cultivating them upon potatoes.

Indisputable proof that the streptococci so cultivated are the contagion which is the cause of erysipelas, lies in the fact that the smallest trace of a pure culture conveyed to a wound produces the typical clinical form of

the disease erysipelas. Fehleisen succeeded in showing this first of all in rabbits, into the ears of which he inoculated the cultures through a small incision. After 12 to 24 hours the most acute inflammation was always present. The skin of the ear was swollen and red; the inflammation extended superficially, and after invading more or less extensive areas of the surface of the body, began at the end of a few days to decline.

The inoculation experiments on men, which Fehleisen made in von Bergmann's Clinic, are equally decisive and still more valuable. These inoculations were undertaken as a mode of treatment for tumours which had been allowed to go beyond the reach of operations, and for some cases of lupus.

As in rabbits the culture of the streptococci was inoculated into small superficial skin wounds. After a definite period of incubation, varying from 15 to 61 hours, the inoculated patient had the characteristic rigor; swelling and reddening of the skin occurred with the same fiery colour and the same advancing edge as in ordinary spontaneous erysipelas; and finally all the signs subsided.

These simple observations bring a burst of daylight on what formerly was wrapped in utter darkness. The periodical outbreak of this disease, the obstinate way in which it would settle in a certain ward, or a certain bed, or cling to some other object is now cleared of all mystery; for we know that the contagion, the streptococci, will flourish and multiply for an almost indefinite period in almost any organic material. The older operators were overcome by an awful wonder, when they operated on three patients in succession on the same table and with the same instruments, and all three, though they occupied different rooms, were at-

tacked by erysipelas. Such cases are no longer miraculous. Either the operator's hands or his instruments were richly supplied with streptococci and inoculated each of the wounds with the same certainty as Fehleisen's cultivations. For us now the miracle will rather be that the contagious nature of erysipelas was not recognised in the light of common experience such as this, and that the old notion of Galen, that erysipelas depended on a bilious condition of the blood, "a biliari sanguine generationem obtinet" prevailed within a few decades of the present time. It was maintained by von Chelius in 1851, and a chapter of Volkmann's famous treatise is devoted to it.

Another contagious affection of wounds, and one of the most fatal, traumatic tetanus, has been submitted to equally conclusive investigations. The contagiousness of tetanus was first proved by Carle and Rattone in 1884. They produced the symptoms of the disease in rabbits with the pus from the wound of a patient suffering from tetanus. In 1885 Nicolaier, working in Flügge's laboratory, discovered that there are bacilli, widely distributed in most soils, which when inoculated subcutaneously into mice, guinea-pigs and rabbits produce typical tetanus, resulting in the death of the affected animal. Shortly after this Rosenbach showed that Nicolaier's bacilli were also present in human tetanus. All attempts to obtain pure cultivations of these bacilli for a long time failed; finally, however, in 1889, Kitasato succeeded, and by experiments on animals, established the fact that such cultivations produce the disease.

Nicolaier's bacilli have a distinctive shape, which has been aptly compared with that of a drumstick. They are peculiar, as Kitasato was the first to observe,

in that they grow only when excluded from the air, but that when this condition has been fulfilled, they will grow readily on most of the usual media, broth, gelatine, blood serum, &c. The best method of cultivating these anaerobic organisms, as they are called, is to inoculate them upon media in closed vessels, in which hydrogen has been made to replace the ordinary air. They grow most readily at the temperature of the body, and at a temperature lower than 18° C. they usually cease to grow. When dried in the air they preserve their virulence for a long time.

If small quantities of tetanus bacilli are introduced under the skin of mice or other animals, after 24 hours the animals become affected with typical tetanus. The parts of the body nearest to the seat of inoculation show the first contractures, and clonic and tonic spasms gradually extend to the rest of the muscular system. The symptoms increase in severity and at the end of two or three days the animal dies.

In the case of erysipelas, we saw that the disease is spread by the advance of the cocci, which are found wherever the symptoms of the disease are to be seen; in tetanus this is not so, the bacilli are not disseminated in the tissues of the body at all; they are to be found only in the pus at the seat of infection. The seizure of one group of muscles after another is not due to the advance of the bacilli, but is the remote effect of a poison or poisons, the product of the growth of the bacilli in the wound, which is taken up by the fluids of the body, and generally in spite of the early removal of the colony that produces it causes the death of the patient. Brieger has isolated several of these poisons, to which he has given the name tetanin, tetanotoxin, spasmotoxin and hydrochloric acid toxin, and which in

small doses will set up typical spasmodic fits in animals.

Tetanus bacilli were found by Nicolaier in the surface-soil of inhabited districts; at greater depths they become rarer; and they are most abundant in the dust of dwellings and in the mud of the streets. This explains how it is that wounds, which have been fouled with dust or mud, or have been made by a splinter from the floor, are particularly apt to be followed by tetanus. The wide distribution of tetanus bacilli would no doubt make it a much commoner disease than it is, if they were only able to grow in ordinary air. They must be thrust deep into the tissues, and not merely deposited on a superficial wound, in order to develop their fatal properties.

As much light has been thrown on the etiology of many other contagious diseases of wounds, as on that of tetanus and erysipelas.

The Staphylococcus pyogenes, different cultivations of which show different colours, a golden yellow, a pale yellow, or white, is now recognised as the cause of ordinary suppurative processes such as boils, whitlows, phlegmonous erysipelas and many cases of pyæmia. A common germ in more severe suppurative processes and and in fatal pyæmia is the Streptococcus pyogenes. The appearance presented by cultivations of this streptococcus and its shape so closely resemble those of the streptococcus of erysipelas, that many investigators regard the two as identical, and the difference between the diseases produced as depending on a difference in the parts affected. Other cocci, for example the Micrococcus pyogenes tenuis (Rosenbach), have less often been found where pus is present.

The appearance of a blue colour in pus, which is ob-

served usually where the wound secretions are profuse, and the nature of which has long been disputed, depends upon the presence of a bacillus (Bacillus pyocyaneus). The bacillus produces a characteristic bluish green pigment in albuminous material, to which air has access. When injected into animals subcutaneously or intravenously, it produces symptoms of violent inflammation and poisoning, but it cannot penetrate deeply into the tissues from the surface of a wound.

Fungi are so constantly found in all suppurative processes, that it can be laid down as one of the axioms of surgery, that without micro-organisms no suppuration, at any rate no progressive suppuration, is possible. For the abscesses, which may be produced by the injection of turpentine or mercury, differ essentially from the suppurative processes in wounds, in that they do not exhibit the dangerous tendency to spread and infect the general system.

The bacilli of anthrax, tuberculosis, glanders and diphtheria have for years been among the organisms, whose biological relations are best known. Two species that are constant in the human intestine, have more recently been recognised as the cause of many cases of peritonitis especially after perforation; these are the Bacterium coli commune and the Bacterium lactis aerogenes; and certain cases of septicæmia and rare forms of gangrene have been traced to other micro-organisms. One disease, however, and that one that was formerly the greatest scourge of all the diseases to which wounds are liable, still remains unaccounted for; and it is to be hoped that occasion to account for it may never again arise. It was the greatest of the triumphs of the antiseptic method of treatment, that

before the dawn of scientific bacteriology, hospital gangrene, that most terrible of all the terrors of the old régime, had been swept from our hospitals.

But it must not be supposed that with the discovery of germs, all the problems of disease have been solved. We know for certain that all progressive suppuration is due to the activity of bacteria, but the origin and course of these infective processes still present many difficulties. The presence of a pyogenic staphylococcus in a wound does not by any means always cause suppuration. There are many links in the chain that are missing. Conditions are imposed upon infection by the individual properties of the micro-organisms, by the state of the patient, and by the state of his wound. We are still treading only upon the outskirts of a new field of knowledge.

We have, for instance, only recently learnt that different degrees of virulence are exhibited at different times by the same organism; and this may explain much that is at present unintelligible. How it is that infection by the same organism, for instance Staphylococcus pyogenes aureus, may present such different clinical phenomena, and that large quantities in one case may be innocuous, while a minute trace in another suffices to produce most severe poisoning, we are only beginning dimly to understand.

Again, morphologically identical staphylococci or streptococci may be found in the most widely different surroundings, in saliva, on the skin, and in abscesses for instance; and one theory, which finds favour with many investigators, is that the same morphological type really includes many different groups. If this be confirmed, it is possible that our difficulties may be still further done away with. The investigations of Kurth

and von Lingelsheim are upon these lines. They are endeavouring to submit numerous streptococci, hitherto thought to be identical, to more accurate tests and to establish distinctions in their mode of growth and pathogenic properties. Different forms of the Staphylococcus pyogenes have already been distinguished by the colours of the colonies, orange, yellow or white. And further analogies have been supplied by the pathogenic organisms known to veterinary surgeons. Different kinds of septicæmia occurring commonly among animals, deer plague, swine plague, chicken cholera, rabbit septicæmia (Koch and Gaffky), ferret plague (Eberth and Schimmelbusch), are caused by bacillary organisms, which have an extraordinary similarity in their external appearances, but which pathogenically are distinct, and exhibit upon careful examination differences of shape and mode of growth.

It is beyond question that the condition of the wound and its position in the body is of great importance in deciding the occurrence and course of infection. A wound which penetrates into a joint cavity, or a compound fracture, has greater dangers than a wound confined to soft parts; the gravity of a compound fracture of the jaw is not the same as that of a compound fracture of the leg; these are familiar facts which are still unexplained. The peculiarly malignant influence of diabetes mellitus upon wound infection is only one of many common clinical experiences, that remind us that we cannot altogether ignore predisposition to wound infection.

Nevertheless, in spite of all these unsolved problems, soon, let us hope, to be solved, it must be insisted that the main factor in the infection of wounds is the inoculation of pathogenic organisms, and that the first duty

of the surgeon is to keep his wounds free from any trace of them. At any rate, our endeavours in this direction have been crowned with a success which is encouraging.

CHAPTER IV.

DISINFECTION.

The different ways in which the germs of wound infection may be attacked—Attempts to mitigate the virulence of bacteria, to destroy their poisonous products, or to produce immunity, have hitherto effected little—The prevention of their growth and their destruction are the only methods applicable to surgery—The selection of a disinfectant—The limitation of our powers in this direction.

THERE are several ways in which we can combat the germs of wound infection. We can,

1. Remove them, without destroying them, by mechanical means such as washing, scrubbing, &c.

2. Kill them by means of germicides.

3. Prevent their development and growth.

4. Modify their virulence by attenuation of their pathogenic properties, or by rendering them incapable of thriving in the animal body.

5. Counteract the poisonous effects of the products of their metabolism by antidotes, without affecting the microbes themselves.

6. Render the body capable of resisting their attacks without directly attacking either the microbes or their poisonous products.

It is right that the removal of germs by mechanical means should come first of all the methods of disinfection.

From ancient times extensive use has been made of this in domestic laundry work, &c., and it was only

from ignorance of the true nature of infection that it was undervalued by the older surgeons. The great value of mechanical disinfection has been scientifically appreciated only since the infection of wounds has ceased to be attributed to impalpable vapours instead of to palpable dust and dirt. Simple cleansing is the first step in every disinfection, and the most strenuous cleanliness in every surgical undertaking is worth as much as or even more than everything else that can be done to guard against the conveyance of disease.

The means referred to under the 4th, 5th, and 6th headings are as yet of very little value in the practice of medicine.

Toussaint and Chauveau ascertained that by heating anthrax bacilli up to between 40° and 55° C., they were robbed of their pathogenic properties and although they continued to grow they had no harmful influence on susceptible animals; and this was afterwards found to hold good for other diseases. From these attenuated cultures substances have been obtained, which when inoculated into animals render them immune against virulent germs. But interesting though these facts are, no one has hitherto been able to make use of them in treating the diseases of wounds.

The investigations of Behring and Kitasato have taught us that blood serum, under certain circumstances, has the power of destroying bacterial poison even outside the animal body. Attempts to make use of these properties of blood serum in the treatment of disease seem to promise the best results in the case of tetanus; but indisputable cases of cure of this disease in man are still wanting. It has further been observed by Charrin that cultivations of bacillus pyocyaneus, inoculated upon rabbits, protect them from the disease

which this bacillus produces in them, and a similar immunity has been conferred by cultivations of staphylococci in the case of dogs and rabbits in Reichelt's experiments. But even these experimenters doubt whether from a therapeutical point of view anything has been gained by these results.

The course of infection with these organisms is not the same in men as it is in animals, and clinical experience of, for instance, pyæmia and furunculosis lends little support to the notion of immunity from suppuration being conferred by recovery from previous suppuration.

Immunity from one infectious disease, hydrophobia, seems to have been successfully established, although the mystery of that immunity remains inexplicable. The greater the number of inoculations carried out at the Pasteur Institute in Paris, the more certainly it seems to be proved that Pasteur has found, for a certain number of cases, a means of mastering this most terrible disease in an attenuated virus, obtained from the dried spinal cords of rabbits inoculated with rabies.

With germicides and means of checking the growth of bacteria, disinfectants in the narrow sense of the word, surgery has been literally flooded ever since the short undisputed supremacy of carbolic acid, so highly recommended by Lister, came to an end. The tests, by which the value of a method of disinfection was decided, were at first very inefficient. It was generally regarded as quite sufficient to show that it could do away with the smell of any foul fluid, or put a stop to the movements of bacteria. More accurate ideas of what true disinfection should accomplish were first promulgated by the classical labours of Robert Koch and his pupils, who have clearly marked out the lines

along which we must proceed in forming an estimate of the value of an antiseptic agent.

In the first place, in order to prove the disinfectant properties of a substance, mixtures of bacteria, such as exist in any decomposing fluid, must not be employed as a test; we must use pure cultivations of the bacteria which produce the infectious diseases of wounds. A silk thread or some such vehicle is impregnated with the germs, by dipping it in a pure cultivation; it is then exposed for a certain time to the action of the disinfectant which is the subject of investigation. After this it is conveyed to a suitable artificial nutrient medium or inserted beneath the skin of an animal, and it is ascertained whether living germs still capable of causing infection adhere to it.

Again, it is important in doing this to distinguish between different forms of the same species of organism; for in addition to the ordinary actively growing form, some species occur also in a quiescent form as spores; and these two forms differ from each other so widely in their power of resisting noxious influences, that we should be led into serious errors if we left this distinction out of consideration. Whilst a weak solution of a disinfectant, *e.g.*, carbolic acid 2 per cent., may be strong enough to destroy anthrax bacilli in a minute, a 5 per cent. solution has no influence upon the spores, even after acting upon them for many days. It becomes, therefore, a matter of great importance to know which of the germs of wound-disease form spores, and which do not.

A. The germs which form spores are:—

1. The bacilli of anthrax.
2. The bacilli of tetanus.
3. The bacilli of tuberculosis.

B. Those which do not form spores are:—

1. Staphylococcus pyogenes aureus, albus and citreus.
2. Streptococcus pyogenes.
3. Streptococcus erysipelatosus.
4. Diphtheritic bacilli (Löffler).
5. Bacilli of glanders (Löffler, Schütz).

Different bacteria exhibit different powers of resistance. The spores of anthrax are generally more resistant than those of tetanus. Among those that form no spores staphylococcus pyogenes is distinguished by remarkable powers of resistance. But even in the same organism the power of resistance varies considerably. There are not only differences between the individual germs, but whole cultures vary in this respect according to their age, to the temperature, to the amount of moisture present and so forth. Some anthrax spores, for instance, are killed after three minutes exposure to nascent steam; while others survive an exposure of twelve minutes (von Esmarch).

These variations in resistance make the examination and comparison of different methods of disinfection no easy matter.

The examination of the disinfectant properties of chemical agents presents special difficulties. It is difficult to prevent the silk thread or other infected substance carrying with it a certain amount of the disinfectant, when it is laid upon the nutrient medium or inserted under the animal's skin. If this is allowed to occur, the nutrient medium is spoilt, and germs that are alive, may still be prevented from growing on it, and so a deceptively favourable result may be obtained. R. Koch, taking these facts into consideration, recommends that the object to be disinfected should be very

small as compared with the amount of the medium on which it is laid, so that any of the antiseptic that may be adherent to it may be diluted as much as possible by diffusion. As an additional precaution in doubtful cases, before attempting to obtain a cultivation, he would remove the disinfectant by irrigation with sterilised water or absolute alcohol. The credit of seeing the importance, in such experiments, of the presence of traces of the antiseptic is unquestionably due to Geppert. He showed that the most minute traces of the antiseptic in the nutrient medium could materially alter the results obtained; that mere irrigation is not sufficient, and that nothing short of the total chemical precipitation of the antiseptic gave correct results. Geppert experimented with anthrax spores suspended in pure fluids, which he mixed with corrosive sublimate in the proportion of 1 in 1000. If samples were taken in the usual way and conveyed into gelatine, the results varied, but often after the sublimate had acted for three minutes no growth occurred. If the sample, before being removed from the sublimate solution, was treated with sulphide of ammonium, the results were considerably altered. Not only did growth occur after the sublimate had been allowed to act for fifteen minutes, but in five experiments even after twenty-four hours. A one per cent. solution of sublimate always gave well formed colonies after six to twelve minutes. Results from the inoculation of animals also prove that we cannot hope to kill the spores of anthrax by the action for a short time of a one per cent. solution of sublimate, that even several hours may not suffice, and that the spores may be active after remaining twenty-five hours in sublimate.

Geppert's results show that the disinfectant powers

of chemical agents have been valued too highly. Total chemical precipitation cannot be so easily effected in every case as it can in the case of sublimate. In the case of carbolic acid, for instance, it is practically impossible. Under these circumstances the traces of the antiseptic must be removed as far as possible by Koch's method of irrigation.

Certain definite conditions are indispensable for the existence of bacteria, as of all forms of life. In the absence of these development and multiplication cease, and sooner or later life is extinguished. These conditions are:—

The presence of certain nutritive substances.
The presence of moisture.
A certain temperature.

The limits within which variations in these conditions may occur, are, if we consider the whole genus of bacteria, very wide; for the germs of wound infection, with which alone we are at present concerned, they are narrower, since they are all alike in being able to thrive and multiply in the human body. There are bacteria which will develop at a temperature much below that of an inhabited room, and again others that do not flourish till a temperature of from 60° to 70° C. is reached; but for the growth of pathogenic organisms the temperature must lie somewhere between about + 15° C. and + 40° C.

It is therefore possible to check the growth of bacteria and at last to cause their death by merely depriving them of the conditions essential to their life. For thousands of years this fact has been made familiar use of in the preservation of articles of diet from putrefactive and fermentative changes. Degrees of cold and heat outside the narrow limits mentioned above are

sufficient to prevent the development of pathogenic germs; and nothing achieves this end more certainly than the concentration of the nutrient media, by the withdrawal of water, till perfect dryness is attained.

Again the development of germs can be checked by adding to the nutrient media chemical substances which are poisonous to them. Agents of this kind are very numerous and of very varying efficacy. The following list compiled by Koch is comprehensive and convenient.

Koch's experiments were made with anthrax, and in the following manner. Anthrax spores were dried upon silk threads, which were placed in small dishes containing ten cubic centimetres of broth or blood-serum. After a time bacilli and distinct anthrax threads developed from these spores. Different antiseptics were then added to other similar dishes of the media, in various proportions, and similarly charged threads put into them; the different proportions which allowed them to thrive, or were sufficient to impede or to completely put a stop to the growth were then ascertained by microscopical observations.

Substances which impede growth, will when present in large quantities, or after prolonged action cause the death of the micro-organisms; but they must not therefore be regarded as germicides. In the above list of substances there are but few germicides, and many that will prevent the growth of bacilli will not kill them, and still less their spores. In spite of its powerful inhibitory influence on the growth of anthrax spores, cold even of the greatest intensity cannot kill them. Pictet and Jung, for example, found that anthrax spores that had been submitted for 108 hours to a temperature of 70° C. and then for 24 hours to one of 130° C., had lost nothing of their virulence or capacity for develop-

ment. Prudden ascertained that the staphylococci of pus are not killed after being kept for months at 0° C. in ice, although of course they cannot develop or multiply at that temperature.

	Growth was distinctly hindered by the proportion of:—	Growth was completely put a stop to by the proportion of:—
Corrosive sublimate	1 : 1,600,000	1 : 300,000
Oil of mustard	1 : 333,000	1 : 33,000
Arsenate of potassium	1 : 100,000	1 : 10,000
Thymol	1 : 80,000	
Oil of turpentine	1 : 75,000	
Osmic acid	1 : 6,000	
Oil of cloves	1 : 5,000	
Potash soap	1 : 5,000	1 : 1,000
Iodine	1 : 5,000	
Salicylic acid	1 : 3,300	1 : 1,500
Hydrochloric acid	1 : 2,500	1 : 1,700
Camphor	1 : 2,500	over 1 : 1,250
Eucalyptol	1 : 2,500	over 1 : 1,000
Borax	1 : 2,000	1 : 700
Benzoic acid	1 : 2,000	
Bromine	1 : 1,500	
Chlorine	1 : 1,500	
Permanganate of potassium	1 : 1,400	
Boracic acid	1 : 1,250	1 : 800
Carbolic acid	1 : 1,250	1 : 850
Quinine	1 : 830	1 : 625
Chlorate of potassium	1 : 250	
Benzoate of sodium	1 : 200	
Alcohol	1 : 100	1 : 12·5
Chloride of sodium	1 : 64	

The germicidal agents we can employ are:—

1. Heat.
2. Various chemical substances.

Heat can be applied by means of:—

1. Hot or boiling water.
2. Steam.
3. Hot air.

Of these boiling water is the most powerful in its action. Anthrax spores are killed by it as a rule within two minutes, and actively growing forms, bacilli and and cocci, in one to five seconds. Bacteria free from spores die after one to two hours in water at a temperature of 60° to 70° C.

Next to boiling water in efficiency comes steam. Its full powers are developed only when it is saturated, that is in the absence of air. It may be made use of under various conditions.

1. Steam in equilibrium.
2. Steam in motion.
3. Steam under pressure.
4. Superheated steam, raised to a temperature o more than 100° C. by passing it, for instance, through heated pipes.

The disinfectant energy of steam in equilibrium is practically the same as that of steam in motion; that of steam under pressure is more powerful, that of superheated steam which is not under pressure, is apparently less powerful. Steam in motion kills anthrax spores in 5, 10 or 15 minutes, according to their powers of resistance.

Hot air is not nearly so powerful as boiling water and steam. Hot air certainly kills bacteria free from spores in 1½ hours; but spores were destroyed only after remaining for 3 hours in air at 140° C. (Koch and Wolffhügel).

Most chemical disinfectants act much less energetically than heat.

Very few chemical solutions will kill anthrax spores within 24 hours, unless they are so concentrated as to be on other grounds objectionable. The following classification of chemical substances is based on recent investigations made by Koch and others.

A. Those which will kill anthrax spores within 24 hours.

Corrosive sublimate.

Iodine.

Chlorine.

Bromine.

Trichloride of iodine (Behring).

Creasol mixed with sulphuric acid (C. Fränkel).

(Trichloride of iodine is a combination of iodine with chlorine as its name implies; creasols are substances contained in raw carbolic acid; they are insoluble in water, but the addition of sulphuric acid dissolves them and at the same time calls into play their disinfectant properties).

B. Those which will kill anthrax spores but require for this purpose more than 24 hours.

Carbolic acid 5 per cent., and other similar distillation products of coal, such as creolin, &c.

Raw wood vinegar. (About two days).

Chloride of calcium 5 per cent. (Five days).

Oil of turpentine. (Five days).

Sulphide of ammonium. (Five days).

Formic acid. (Five days).

Chloride of iron 5 per cent. (Six days).

Picrin chloride 5 per cent. (Six days).

Quinine 1 per cent. in hydrochloric acid. (Ten days).

Arsenic acid 1 per cent. (Ten days).

Hydrochloric acid 2 per cent. (Ten days).

Æther. (Thirty days).

C. Those which have no effect on anthrax spores even after acting on them for months.

Absolute alcohol.

Distilled water.

Chloroform.

Glycerine.
Benzoic acid.
Sal ammoniac.
Concentrated salt solution.
Chloride of potassium five per cent.
Alum.
Borax.

This classification of course does not hold good for the destruction of actively growing bacilli and cocci. For this purpose many of the substances in Group C, as well as those in Groups A and B are sufficiently strong; for instance absolute alcohol and chloroform. But even so their action is by no means as rapid as that of heat, which takes effect in a few seconds, where they would as a rule require much longer. The disinfectant power exerted by these substances on cocci and bacilli was formerly much over-estimated, just as it was in the case of anthrax spores. It was supposed, for instance, that 1 in 1000 sublimate solution killed cocci in a few seconds. Whereas if precautions are taken, such as Geppert recommends, this strength of sublimate solution cannot be relied upon to kill staphylococcus pyogenes and bacillus pyocyaneus even after ten to fifteen minutes.

But it is not enough that a disinfectant should destroy bacilli or check their growth; it is even more important that it should be adapted for the particular uses to which it is to be put. Because its energy is proved on bacteria suspended in water or broth, or dried upon a silk thread, it does not follow that it will meet all the exigencies of surgical practice. Experiments with impregnated silk threads are conducted under the most favourable conditions for disinfection. The quantity of the antiseptic is very large, there is

nothing to hinder its action and each individual germ is immediately exposed to its influence. In practice we scarcely ever have to do with bacteria under conditions which make disinfection so easy. They generally are found massed together, enclosed by dirt of all sorts, and protected by different substances which can hardly be penetrated. In order to overcome these different obstacles to complete disinfection, different disinfectants must be selected for different conditions.

Nothing is more important, for the development of the germicidal power of a chemical agent, than that it should be dissolved in some fluid which will penetrate into the object to be disinfected. The most powerful antiseptics dissolved in oil are quite inoperative, when we have to do with germs that are dried on a silk thread or that are moistened with water, for the oil does not reach the organisms, and the antiseptic is, as Robert Koch proved, useless. The same applies to antiseptics dissolved in water, when we have to kill bacteria enclosed in fat and layers of dirt. Under such circumstances the strongest solutions of sublimate and carbolic acid take absolutely no effect. It is easy to prove, for example, that silk threads impregnated with suppurative fungi can lie for days and weeks in a 1 in 2000 solution of sublimate, without the bacteria dying, if the threads after impregnation have been dipped in oil, so that the fungi are embedded in the greasy material. These considerations are of great moment in surgical practice. Not only does the surgeon make free use of grease and oil to lubricate bougies, catheters, and his fingers in a digital examination, but Nature gives still more abundant opportunities for bacteria to protect themselves from antiseptics dissolved in water by a covering of fatty matter both in wounds and on the surface of the skin.

Again the chemical composition of the objects to be disinfected may present important considerations in the use of chemical disinfectants. There is a great difference between bacteria in a dry condition, or suspended in water or broth, and bacteria mixed with blood, sputum, fæces, &c. When we have to deal with substances which are capable of entering into chemical combination with the antiseptic, the process of disinfection is much modified. We had occasion to show above, how Geppert, in his disinfection experiments, made the sublimate present in silk threads innocuous by dipping the threads for a short time in dilute solutions of sulphide of ammonium, so as to convert the sublimate into insoluble and inactive mercuric sulphide; when we have to disinfect substances which may contain unstable combinations of sulphur such as sulphuretted hydrogen, sublimate may easily be rendered ineffectual by being converted into an insoluble form, so that the disinfectant action, which is intended, does not take place. In the disinfection of sputum and fæces, the strikingly unfavourable results given by antiseptics, which under other circumstances are justly prized, may be explained by the occurrence of this decomposition. Gerloczy succeeded in proving that a concentrated solution of sublimate in water was incapable of disinfecting an equal quantity of fæces. Antiseptics which are much weaker than sublimate, such as lime for instance, may for this purpose be much more effectual.

The presence of albuminous substances, blood, or pus considerably impairs the action of many chemical disinfectants. This is true even of the strongest, for instance metallic salts like sublimate and substances of the aromatic group, carbolic acid, creolin, &c., and is therefore especially important.

On the ground of general utility no less than that of destructive energy, heat is superior to chemical means of disinfection, in that its action depends less upon external influences that are hard to calculate, and in that it has a far greater power of penetration. This is true of steam and boiling water especially, which are superior to heated air when greasy masses have to be dissolved. The hot air method is objectionable also when large objects such as beds, linen, or dressings have to be disinfected. Into such objects it penetrates with difficulty. The experiments of Koch and Wolffhügel have thrown light on this point; they heated among other things a packet of woolen blankets measuring 72 c.m. by 36 c.m., and 106 c.m. in circumference; after three hours exposure to a temperature varying from 152° to 160° C., they found that the temperature inside the packet varied from 70° to 95° C. M. Gruber found that a similar packet was not heated throughout to a temperature of 100° C. till one hour forty-seven minutes had elapsed; whereas steam produced the same effect in eight minutes.

The length of time required for any particular mode of disinfection to kill bacteria also bears upon its utility. If we require to kill spores in minutes and actively growing forms in seconds, chemical disinfectants which take longer than this are of no use. In this respect too boiling water and steam are superior to hot air.

In choosing between chemical and physical agents, we must also take into consideration the effect of their action upon the objects to be disinfected. In some cases many excellent disinfectants are altogether excluded. Sublimate, for example, cannot be used to sterilise metal instruments, because it attacks and destroys them, and high degrees of heat cannot of course

be made use of in disinfecting living tissues, for instance, the hands of the surgeon and the skin of the patient. Similarly many chemical agents must be excluded on account of their poisonous effects on the human body; while hot air cannot be used to disinfect textile fabrics because after some hours it makes them brittle.

The choice of a disinfectant is therefore never a simple problem, one solution of which is applicable for all circumstances; the following points must, in each case, be taken into consideration:—

I. The nature of the object to be disinfected.

II. The resisting power of the germs to be killed or rendered innocuous.

III. The disinfectant energy of the agent used.

IV. The obstacles to disinfection presented by

(*a*). The size and shape of the object.

(*b*). The presence of dirt and fat.

(*c*). Chemical reactions.

V. The length of time occupied by the process.

Two further considerations need no discussion:—

VI. The necessity for special knowledge and skill in those engaged in its use.

VII. The cost.

There is no one disinfectant, of course, that can, under all conditions, satisfy all requirements. Different methods suit different conditions. But the use of chemical agents, formerly so generally confided in, must, in the light of recent researches, be considerably restricted; while heat because of its superiority to chemical agents in germicidal energy, in power of penetration and in range of applicability, must be most widely made use of.

Neither can we always be content when one method

of sterilization has been carried out; a succession or combination of different methods must often be employed. The removal of dirt by mechanical means, for instance, is a preliminary step that must precede all other measures; and our goal is reached only after a combination of chemical agents, or of these together with heat, boiling in soda solution, for instance, has been subsequently made use of.

Subsequent chapters will be devoted to the detailed discussion of the methods applicable for the disinfection of the various objects employed in the treatment of wounds taken in order.

One point only remains to be clearly brought out at this stage and from the outset must be clearly borne in mind, and that is the necessary limitation of the degree of disinfection that is attainable, and to be aimed at in practice. To the question, what should disinfection accomplish, in the early days of the antiseptic era, the short and concise answer was, that all bacteria must be destroyed. At that time we were not yet acquainted with the biological peculiarities of micro-organisms; we were not aware of the existence of spores, a form of fungus life endowed with powers of resistance to damaging influences, unlike those of any other forms of life. Now we know that there are several kinds of spores, which can withstand boiling and steaming for hours without taking any injury. We know that spores of the hay bacillus and those contained in garden mould are found to be still alive after two hours exposure to nascent steam; and Globig has made us acquainted with spores of a bacillus, growing on potatoes, which preserve their vitality after boiling in water for four hours. If in giving directions for disinfection, we based our calculations upon the vitality of the spores of this

bacillus, the most resistant known to us, and gave orders for our instruments to be boiled or steamed for hours, we should be holding up an ideal, that of exterminating every kind of germ, which would be quite unattainable in ordinary practice. But these fungi are of absolutely no pathological significance for men; and it must be laid down as an axiom once for all, that our measures for disinfection need not be directed against organisms that have no pernicious effect on wounds.

In veterinary pathology disease germs are met with which have extraordinary powers of resistance. The spores of symptomatic anthrax, popularly known as quarter evil, and of malignant œdema are far more resistant than those of anthrax. It is possible, though not positively proved, that both these diseases may also attack men; and it is quite conceivable that organisms with similar powers of resistance may be found to account for certain peculiar and severe inflammatory processes ending in gangrene, which now and again occur in men, and have not yet been explained by bacteriology. In dealing with them we can devise measures of greater disinfecting energy, and all objects which come in contact with the suspicious virus, can be sterilized more carefully than at other times.

A further distinction, which stands out all the more clearly in clinical experience, from the fact that in the prompt results of laboratory experiments it seems to disappear, is the distinction between germs that are pathogenic but not infectious, and those which are infectious as well. It does not necessarily follow because a disease is caused by a fission-fungus, and its germs are inoculated without failure from one animal to another, that the disease is therefore directly contagious. One of the most terrible diseases, noma, popularly known in Ger-

many as "wasserkrebs," in all probability depends on a bacillus which grows sparsely in the tissues attacked, and causes them to become gangrenous, and yet this disease has occurred only sporadically, or at most in a few simultaneous cases. It has never taken on the character of a true epidemic, and has, as far as is known, never been conveyed from one individual to another. Moreover the diseases with which we are most familiar are not all equally likely to bring with them dangers of infection. Tuberculous affections for example are treated in hospitals almost daily, and the tuberculous material by no means always carefully dealt with, and yet the infection of a fresh wound with tuberculous disease has been practically never observed. In the case of anthrax again it was formerly maintained that the disease might readily be conveyed from animals to men but never from man to man; and certainly even modern improved methods of observation have brought to light only very few instances of the latter mode of transmission. On the other hand there is not the slightest doubt that erysipelas and suppurative processes attack case after case, unless special precautions are taken with the wounds and all infected material. The germs therefore against which our efforts must be directed are those which are infectious. They fortunately are among those which do not form spores and are therefore easy to kill. If our wounds are successfully kept free from erysipelas, suppuration and septicæmia, the problem of disinfection is almost solved; and for this purpose all requirements are fulfilled, in at least the great majority of cases, if we take as the standard to aim at, such measures as are sufficient to destroy anthrax spores; much more than this we seldom attempt.

But whatever standard is fixed upon, special care will still be necessary in cleansing and disinfecting instruments which have been used for cases of purulent œdema. Stereotyped rules are not what is required so much as discrimination in adapting our precautions to the dangers presented in each instance.

CHAPTER V.

Disinfection of the Surface of the Body.

Numerous fission fungi are always present on the surface of the body—Disinfection of the skin and hands—Disinfection of mucous membranes—Disinfection of the utensils employed in cleaning the skin—Soap—Brushes.

Since Eberth in 1875 demonstrated the presence of numerous bacteria in normal sweat, and described the colonies which they form on hairs, many investigators have been engaged in the examination of the microbes on the surface of the body, and have brought to our knowledge an extraordinary number of species, quite a flora.

Whilst the internal tissues are free from germs, the surface of the body swarms with bacteria of diverse kinds; mould fungi, budding fungi, bacilli, cocci, and varieties which produce pigment and aromatic substances, are found in countless multitudes. This is indeed no wonder, for all the conditions required for the growth of the lower organisms, are found on the surface of the body.

An equable temperature favours their growth, the secretion of glands of the skin and mucous membranes affords the necessary moisture, dead cells of the epidermis and animal and vegetable substances from manifold sources provide the necessary nutriment. A cursory examination by modern methods is sufficient to convince us that they are present in large numbers. All that is necessary is to press a cover-glass on the

damp skin or mucous membrane, or to soften a few scales from the skin in dilute acetic acid or potash on a slide; and then after drying and heating for a short time in a spirit flame to colour the preparation in methylene blue, numerous micro-organisms can then be seen under the microscope. It has not hitherto been possible to show that the organisms on the skin belong to certain classes all of which are constantly represented; it appears rather that a very great variety may be found, and that sometimes one, sometimes another is present in the greatest numbers. It is possible that Bordoni is right in supposing that in every country or district, and perhaps even in every occupation, the organisms found on the skin are different, and that the differences depend upon the organisms with which men are brought into contact in their business. We so constantly come into contact with substances that harbour bacteria, and the bacteria so readily adhere to our skin, that each change in occupation, even with common cleanliness, leaves upon us its mark in the shape of micro-organisms. Nothing is more instructive, in relation to this, than the observations of Fürbringer. He was able to show that after occupying himself in his garden for a time, the bacilli of garden mould clung to his finger nails although he had washed his hands. At another time he had some simple examination of some samples of urine to carry out, and some time afterwards found upon his hands in large numbers the micrococcus ureæ, the germ which causes the alkaline change in urine after evacuation. The parts covered with hair, and those where the secretion of sweat is profuse, the axillæ, interdigital folds and crena ani are the parts on which bacteria breed most readily. The cavity of the mouth (Miller) and the whole alimentary tract normally

harbour fission fungi in great numbers. Large quantities of fungi are found in the female genital tract as far up as the internal os (Winter), in the upper part of the respiratory tract, and in the lower part of the urethra. The conjunctival secretion and the cerumen of the ears are also rich in germs of this kind.

Large as the numbers are when the conditions are normal, any trifling disturbance of the normal conditions causes an incredible increase in their numbers. An increase in the secretion, a slight catarrh, or a mild attack of eczema is sufficient to multiply them a thousand-fold, and where a suppurating wound exists, a fistula, shallow ulcer, sloughing cancer, or anything of that kind, the number becomes incalculable. We do not as yet know for certain, whether the dreaded germs of suppuration, and those of severe pyæmic and septicæmic diseases, are regular or common parasites of normal skin. Occasionally, without doubt, they are to be found, as experiments show, and it is only reasonable to infer from the richness of our parasitic flora that pathogenic fungi, should chance or occupation bring us in contact with them, would flourish and multiply in the skin and mucous membranes, no less than the other diverse organisms which may do so.

The cleansing of the body surface, and the removal of the numerous possibly pathogenic organisms adherent to it, is one of the chief problems of asepticism. Wherever a wound exists or is to be made, the surrounding skin must be thoroughly and widely disinfected, so that no germs may reach the wound and lead to the dreaded disturbance in its healing. The hands of the surgeon, much more than the skin of the patient, require the most thorough disinfection before they are allowed to approach a wound. The surgeon's hands

are to be regarded with special suspicion; they are constantly coming in the way of contagious matter, which adheres to them with great readiness, his business being so often with purulent and inflammatory products. At no time is it more important for the surgeon to keep in mind the πρῶτον μὴ βλαπτεῖν of Hippocrates, than when he is about to approach a wound with his hands. And no exceptions should be made; for even wounds that are already diseased, can be still further infected. Erysipelas can attack a wound that is suppurating benignantly, and putrefaction occur in one that is erysipelatous, or purulent œdema and general sepsis either of these. The disasters, which in the past have been and are still very often occasioned by a surgeon's uncleansed hands, can scarcely be credited, and times without number have surgeons, with the best intentions, instead of preserving the life and health of their patients, been the cause of suffering and death.

The disinfection of the skin and hands is unfortunately no easy matter, and the demands made by asepsis on this score, occasion particular difficulty and discomfort. At the commencement of the antiseptic era, when faith in the omnipotence of carbolic acid was unbounded, the disinfection of the surgeons hands was simple enough. It was considered quite sufficient to merely dip them for a minute or two in one in thirty or forty carbolic acid solution; the disinfection was at once completed. In one of the best known introductions to antiseptic treatment (Watson Cheyne, 1882) we read that washing with soap and water is a work of supererogation. How little can be effected by dipping one's hands in carbolic, and how much by the soap and water of which Lister's pupil spoke slightingly, has been shown without discrepancy by practical experience and laboratory ex-

periment. And this is the work of the ten years since the above mentioned treatise was written. It is no exaggeration to say that the result of merely dipping one's hands in even a strong solution of carbolic is qua disinfection nil. If the germs on our hands were as easy to kill as those dried on a silk thread or suspended in broth, we might hope to effect something by a longer action of the solution. But there are no bacteria more difficult to kill than those in the skin, embedded as they are in dirty greasy material, and lying in cracks and crevices, where albuminous and dead organic matter is abundant. Even the strongest antiseptic solutions have not the slightest effect upon this protective covering; sublimate solution runs off in drops from the greasy skin, without even moistening it, while the number of germs in the creases of the skin and under the nails is practically undiminished.

Numerous investigations upon this subject have been published, and the disinfection of the skin has already an extensive literature of its own. Kümmel and Fürbringer were the first to lay the foundation of a scientific disinfection of the skin, and the results of their investigations have not been essentially altered. Dissolving off the dirt, in which the organisms lodge, by the use of as much warm water and soap as possible, supplemented in some cases by that of alcohol or ether (Fürbringer), and removing it by scrubbing with brushes and rubbing with towels, will always be the most important elements in disinfection of the skin. The number of the antiseptics, recommended from time to time as the best and most certain for this purpose, is amazing; but chemical disinfectants only play a subordinate rôle here. As a matter of fact many operators entirely discard antiseptic agents for disinfecting the

skin, and confine themselves to the most minute and careful washing, with admirable results.

Disinfection of the patients skin and surgeon's hands is not a question of the use of this or that disinfectant, but to a great extent one of scrupulous care and intelligent thoughtfulness. The antiseptic may be selected to suit the particular case, with reference to the sensitiveness of the skin and so forth. It is not easy to lay down rules as to the length of time for which hands should be soaped and scrubbed. Practice and skill clearly will accomplish more in a short time than half hearted measures in ten times as long.

In von Bergmann's clinic, following Fürbringer's directions, hands are disinfected in the following manner:—

1. The skin is energetically scrubbed with soap in water, as warm as possible for at least a minute.

2. It is then carefully dried and rubbed with sterilized towels or pieces of gauze, particular attention is paid to the creases and folds of the skin, which are cleaned with a wire nail brush. The space under the nail is the part that is richest in germs (Fürbringer, Mittmann and Preindelsberger), and therefore requires special care.

3. The skin is rubbed with a piece of sterilized gauze and eighty per cent. alcohol for about a minute.

4. It is then washed and rubbed with towels and one in 2000 solution of sublimate.

When the skin is very dirty, as in the case of labourers, or if it peels off very easily from having been long done up in dressings, it is advisable to rub the skin with ether before the above procedure. This removes coarse dirt excellently. When dirt is very much ingrained, or especially if infectious material has been in contact with the skin, this process should be repeated.

The surgeon must also take care to clean himself thoroughly after each time that he touches infectious material, especially after handling suppurating wounds, as well as before each operation or examination, not only from the lower motive of personal safety, but also and much more to prevent infectious germs adhering to and settling on his hands.

Baths take the chief part in disinfecting the skin of the patient, especially that of the trunk. One or more baths should always, if possible, be ordered before operating, and good bathing arrangements are among the most important accessories to aseptic appliances in surgical hospitals. Should bathing be impossible a more thorough soaping must take its place.

The skin must be shaved widely around the wound, or field of operation, not only to remove hairs to which many germs always adhere, but also to scrape off the superficial layers of the epidermis, which are usually very rich in organisms. The use of the razor for the scalp must be somewhat limited by considerations of appearance, but even there the hair should be removed for a distance of $1\frac{1}{2}$ to $2\frac{1}{2}$ inches from slight skin wounds and superficial incisions. A second scrubbing with soap, rubbing with alcohol and drying with towels, must follow the shaving.

When the surgeon has carried out, in the most thorough manner, these essential mechanical cleansing measures, he can reckon on their results with certainty. Unless it is absolutely necessary of course, aseptic operations should not be undertaken directly after a post-mortem examination, or incising phlegmonous erysipelas; but should the necessity arise, repeated applications of the above disinfectant measures will remove the danger of the undertaking.

It has often been proposed that the operators hands should be covered, and more especially the grooves round the nails, and the creases in the skin filled with a firm aseptic paste made, for instance, of carbolic acid, camphor and bole (Schneider), so as to prevent the dangers of contagion. This proposal may be attractive, but no paste can be made to cling to the hands firmly enough to withstand handling, it is bound to crack and chip off, and the result must be most unsatisfactory.

Greasing the hands, however, may sometimes be of value, but only as a measure of self protection, and not because it is a safeguard against the inoculation of germs present upon the hands. After the hands have been well oiled, germs suspended in watery fluids adhere less readily to them, and can be removed from them more easily; and so before vaginal, rectal, or post-mortem examinations, this practice is a sound one.

The disinfection of mucous membranes is a much more difficult matter than that of the hands. It cannot generally be carried out satisfactorily.

In operations, therefore, on mucous membranes, with their abundant stock of bacteria, we cannot make certain of an aseptic course, as we can in case of wounds of skin that can be thoroughly disinfected. The aims of our treatment have, therefore, to be modified, we cannot, for instance, hope for primary union. If only irrigation, with strong disinfectants, effectually disinfected mucous membranes, all our difficulties would be at an end, but unfortunately antiseptics fail here as we saw they did with our hands, and irrigating the vagina with 1 in 1000 solution of sublimate has not the slightest effect on the number of germs in it (Steffeek). But besides being useless, the application of any strong antiseptics to mucous membranes is

dangerous, because owing to the extremely rapid absorption of fluids by most mucous membranes, the risk of intoxication is great. Copious injections of sublimate into the vagina have often brought about serious poisoning, and irrigation of the rectum with the same agent would very likely directly cause death, owing to the great absorptive power of the rectal mucous membrane. Besides most antiseptics stimulate the mucous membranes, and lead to an increased secretion ; this may even cause catarrh or positive destruction and cauterization, and have the opposite result to that desired, increasing instead of decreasing the number of micro-organisms. The only process, by which any disinfection of mucous membranes can be effected, is simple mechanical wiping or washing; the finger or pads of gauze or wool may be used to clear out cavities, and filth and mucus may be mechanically washed away. Simple warm water or some innocuous irrigation fluid is best for this purpose. Weak solutions of boric acid, permanganate of potassium, acetate of aluminium, boiled normal salt solution, and in many cases, for instance, after operations in the mouth, the popular camomile tea are suitable applications. In operations on the alimentary canal, as copious an evacuation as possible is of course to be aimed at ; the contents being rich in bacteria, several days are usually necessary for proper preparation. In rectal and intestinal operations the bowels should be thoroughly opened, and, if possible, repeated enemata ordered. And similarly before operations on the stomach, it should be repeatedly washed out.

Bland laxatives, such as castor oil or Epsom salts, are the best. It has been repeatedly asserted, but never certainly proved, that the bacterial contents of

the intestines can be acted upon by medicine. Stein has not been able to establish any disinfectant action in the agents recommended for this purpose, such as calomel, salol, naphthalin, naphthol, camphor, thymol, quinine, claret, &c.

In disinfecting the skin and mucous membranes, it is hardly necessary to say that everything used in the sterilizing proceedings must be free from germs. All manipulations with the object of disinfecting a patient, must obviously be undertaken only after the surgeon has disinfected his own hands. For precautions as to the water, which is the chief thing used in cleaning, we must refer to Chapter XIII. There must be no possibility of germs being imported instead of removed.

Pads of gauze or wool, as well as towels must be sterilized in steam. Towels fresh from the laundry may, in case of necessity, be used without disinfection in steam, for they are almost free from germs, provided that no contamination has taken place since they were washed. Alcohol, ether, or oil of turpentine, used for the removal of fat are, with ordinary cleanly handling, free from germs. As to soap, those kinds which are prepared by the hot process, by boiling, must be free from germs (von Eiselsberg, 1887). Soap can only contain micro-organisms when hastily manufactured, the saponification of the animal fats, often very rich in bacteria, being in that case carried out by the cold process, the manufacturer must therefore be questioned upon this point. The bran of almonds is on the whole seldom used, but it always contains large numbers of micro-organisms, and could only be used after thorough sterilization, it is best to discard it entirely.

Brushes require special attention, and unfortunately too little care is generally taken with them. The

brushes are carelessly allowed to lie about for weeks or months on washing tables, and are taken straight from them to be used for disinfecting. It is obvious, that a brush, which has been used to remove pus or fæces from the hands of a surgeon, must take up these substances, and being so infected may pass on the germs, which are left in it, when next used. Besides the brushes in general use are wet, and as they contain plenty of albuminous substances in the form of epithelium, pus, or blood, they become regular breeding places for microbes. Repeated investigations have shown that the brushes in wards, post-mortem rooms, and laboratories, contain innumerable germs. It is easy to understand how a brush that has been used to clean skin may contain thousands of bacteria (Schimmelbusch and Spielhagen).

Surgeons, who have been alive to the need for aseptic brushes, have tried to meet it in various ways, by frequently disinfecting the brushes, by using new ones for every major operation, or by completely discarding them and using other things instead. Neuber, for example, being convinced that the ordinary brushes cannot be clean, and believing that they cannot be satisfactorily disinfected, has entirely banished the nail brush from his wards, and has substituted for it small bundles of wood shavings, which can be thrown away after being once used. These bundles of shavings, which are already in use for cleansing purposes in many households, can be sterilized in steam, can be easily kept in stock in large quantity, and are so low in price that even a large use of them is not a serious consideration, in fact a new bundle can be used for each washing. They cannot unfortunately entirely take the place of brushes, the thorough cleansing of corners and creases

in the skin, so satisfactorily accomplished with a brush, cannot be effected with a coil of rough wood shavings. To the practice of using new brushes for each operation no objection can be raised from the point of view of asepsis, there is no safer plan than that of destroying anything that has been once used; but on grounds of economy this is impracticable.

But the difficulty of keeping common brushes, the ordinary cheap nail brushes made of wood and bristles or vegetable fibre, free from organisms is not really so very great. It is quite enough to keep them always in 1 in 2000 solution of sublimate, by this means even those in constant use are kept free from germs. No doubt if they are steeped in pus and full of sticky greasy material, the sublimate would be ineffectual, and certainly would take effect too slowly. Brushes, therefore, that have been infected to this extent, should be boiled or disinfected by steam after being used or before major operations. The vast difference, between disinfection by boiling water and that effected by 1 in 2000 solution of sublimate, becomes evident when attempts are made to sterilize a brush strongly infected with pus. Whilst the number of germs may be unchanged after ten minutes in the solution of sublimate, the brush is absolutely sterilized after dipping for one minute in boiling water. The great value of letting the brushes lie constantly in sublimate is, in the first place, that the development of such germs as may have got on to them during their use is prevented, and secondly, that slowly and gradually, if a sufficient interval is allowed before the brushes are used again, the germs are killed. Brushes should be present on every surgical washing table, lying in a basin of sublimate solution, they are indispensable for thorough purification. The brushes

stand the soaking very well, at any rate for weeks, and they are improved by becoming softer. With moderate use it is sufficient if this solution be renewed once a day, for even if soapsuds be allowed to get into the solution its disinfectant properties are not counteracted, as has been proved by special investigations.

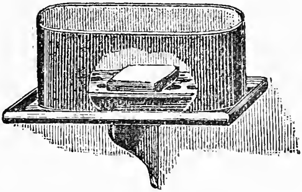

FIG. 2.—Basin for soap.

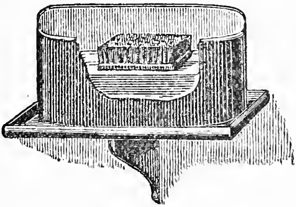

FIG. 3.—Basin for keeping nail brush in solution of sublimate.

The treatment of nail brushes in von Bergmann's Clinic is carried out in the following manner :—

1. New brushes are exposed to nascent steam for thirty minutes before they are taken into use.

2. The brushes are constantly kept in 1 in 2000 sublimate solution, which is changed at least once a day.

3. Every time the brushes are used they are washed out in water as hot as possible, or boiling, before being again laid in the sublimate solution.

On every washing table are placed special enamelled basins for soap and for the sublimate solution, in which the brush is kept.

CHAPTER VI.

Sterilization of Metal Instruments.

Placing instruments in a dilute carbolic solution, before an operation, is not sufficient—Importance of mechanical cleaning—Disinfection of metal instruments by heat—Disinfection in hot air—In steam—In boiling water—Sterilization in carbonate of soda—Advantages of the same—Apparatus for soda sterilization—Patterns of instruments.

All instruments, which come into contact with a wound, must, of course, be absolutely clean. Amputation saws, forceps, dissecting forceps, &c., must be sterilized every time before use, nor must the probes so much in favour with the surgeon, though often so fatal to the patient, be forgotten. Particular care must be expended on metal instruments, since many have to be used at one time in fresh aseptic wounds, at another time in highly infectious, suppurating and putrefying ones. Other things as, for example, pieces of dressing, sponging materials, sponges, drainage tubes, &c., we can simply throw away after use in a bad septic case, or at least, having disinfected them, never use them again for a fresh wound. We cannot, of course, do this with our instruments, the tools to which we have become accustomed and which are necessary to our practice. Thus it may happen that a surgeon who has just operated upon phlegmonous erysipelas, may be obliged to perform herniotomy with the same instruments shortly afterwards.

Formerly it has usually been the practice to lay metal

instruments a short time before and during the operation in antiseptic solutions. Solutions of carbolic acid have been most generally preferred for this object. We must, however, fall into no delusions as to the strength with which these solutions can be used for this purpose. It is not the effect of the antiseptic on the instruments, although knives lose their edge if allowed to remain any length of time in carbolic acid, but rather the effect on those who have to hand and operate with them in this solution, that we have to think of. Lengthy manipulation in five per cent. carbolic is obviously impossible, but even three per cent. solutions are also impracticable, when it is a question of operations lasting a long time, and of handing instruments for hours, possibly every day in this solution. Even persons, who are not especially sensitive to this antiseptic, suffer from eczema, or at least from severe maceration of the skin of the hands, and not rarely from carboluria and more or less unpleasant disturbances of the general health. With or without the knowledge of the operator, the assistant, who hands the instruments, is apt to decrease the strength of the solution, in order to escape from these unpleasant consequences. In von Bergmann's clinic the carbolic solution, formerly used for placing the instruments in, could not be borne stronger than two per cent., and that only by a few for any length of time.

After what we have said on this subject in Chapter IV., and a consideration of the fact that during use the instruments are usually much soiled with blood, pus, and fat, we shall not be inclined to attach much importance to the use of antiseptic solutions, at any rate to that of a two per cent. solution of carbolic acid for a few minutes. The good results that have been obtained by this process, and the good repute that it enjoys with

many operators, are not to be ascribed to the short action of the weak solution of carbolic, poured over the instruments shortly before the operation, but to other accessory factors in the preparation. Were the instruments not subjected to a thorough cleansing after each operation with soaping, scrubbing, washing and drying, and so did not come into the carbolic acid bath in a more or less aseptic condition, the results might be quite different. To be convinced of the inefficiency of carbolic used in this manner, it would only be necessary to operate on a series of cases, some septic others aseptic, with the same instruments lying in such a carbolic solution. The disinfectant value of carbolic, used in this way, is to be estimated at almost nil. The advantage, which it offers, depends upon the fact that the instruments are preserved in a fluid tolerably free from germs during the operation.

The point to lay stress upon, in all methods of disinfecting our instruments, will always be the mechanical process of cleansing, to which they are to be subjected after each occasion on which they are used. Particles of fat, pus, and tissues, in which micro-organisms can and will lodge, must be mechanically removed. This has been carried out in von Bergmann's clinic in the following manner for years. When the operation is over, the instruments are first of all thoroughly rinsed with ordinary water, they are then laid in a hot solution of soda and soap, and are carefully and energetically scrubbed in every part with a brush. Then follows another rinsing and cleaning with alcohol and a piece of leather. Once more rinsing them in a solution of soda, and carefully drying closes the procedure.

All particles of pus and coarser contaminations are got rid of entirely by these manipulations, but even

then of course the instruments are not absolutely free from germs. They still contain varying numbers of fission fungi, which partly adhere very lightly to the instruments. According to the investigations, which we have carried out, the number of germs is certainly not great, it varies according to whether the instrument is easy or difficult to clean, is smooth or has many corners and niches.

This simple mechanical cleansing may have sufficed, as we have said, for many cases, and may still suffice; but where we have metal instruments to deal with we are not dependent upon a process such as this in which thoroughness is hard to control, we can use methods of sterilization that are absolutely certain. Metal instruments can be made free from germs in

1. Hot air.
2. Steam.
3. Boiling water or other boiling fluids.

That is, we can expose them to the most powerful means of sterilization that we know of.

Hot air, long ago introduced into bacteriological laboratories for sterilizing instruments, has been strongly recommended again and again, even in quite recent times for surgical purposes. Some years ago it appeared as if it would enjoy a more extended use in surgical practice. Hot air is indeed far superior to chemical disinfectants not only in the energy with which it kills germs, but also in its power of penetrating through protective layers of fat and dirt (see Chapter IV.). In order to free instruments from the bacteria without spores, an exposure of several minutes would be quite sufficient, but on the other hand to kill anthrax spores, it would be necessary to heat them for three hours at 140° C., or about two hours at 150°-180° C. The experiment was made in the

Royal Clinic of introducing a thorough system of hot air sterilization for metal instruments. But it was very soon found to be impracticable for this purpose and we now believe, that though it may be useful for some special purposes, for most objects of surgical practice it is useless. The chief objection against hot air sterilization is, that it is clumsy and takes much too much time. As above stated, in order to kill resistant spores, using a temperature of from 150°-180° C., an exposure of two hours is necessary; in order to bring a good air sterilizer up to this temperature 20 to 30 minutes is needed on an average, and about the same length of time is necessary for the instruments to get cool. Thus the whole process of sterilization takes up about three hours. How can this be managed? Let us suppose we are about to undertake the task of sewing up the tendons after division of the flexors of the arm, or of operating on a strangulated hernia suddenly; we shall soon give up the idea of a process of sterilization for the necessary instruments lasting several hours. Poupinel (1888), who was warmly in favour of hot air sterilization, and was conscious of this difficulty, proposes to sterilize all instruments the day before the operation, and to keep them in cases in which they have been heated, and so to make provision beforehand for the whole day's programme. The possibility of such a preparation may be granted for some operations, which may be precisely foreseen, as for example an ovariotomy. But when it is a question of a succession of very different operations, or of the common unexpected emergencies in which a definite programme cannot be made out beforehand, it would be necessary to have a store of instruments, which only few could procure, in order to prepare against all eventualities the day before. And

should some indispensable instrument happen to fall and become soiled, one would simply be obliged to change one's tactics and to choose some other means of disinfecting it.

Attempts have been made to shorten the hot air process. An apparatus has been devised which can be brought in a few minutes to an extraordinary heat, and temperatures of more than 180° C. have been tried with a view to gaining time. But these have failed upon the whole because of the technical difficulty of maintaining regular temperatures after quick heating or with very high degrees of heat. Even with ordinary hot air sterilizers it is felt to be a serious disadvantage, that such great variations occur in the disinfecting chamber. We have had occasion to examine hot air sterilizers by the best makers, and have been astonished by the wide range of error in them. A difference of more than 100° between the temperature at the bottom and at the top is common.*

High degrees of temperature and frequent warming up to 150°-180° C. change the molecular arrangement of the steel, converting it into iron, and our instruments are thus for ever robbed of their hardness and edge.

A final objection, which at first sight appears surprising, is that steel instruments very often rust when sterilized by hot air. This *à priori* might seem impossible, since in this method hot, and therefore very dry,

* This is proved most simply by putting in small polished plates of steel. If they are laid in different places in the heated hot air sterilizer, the steel may be tarnished grey and blue at the bottom, yellow in the middle, and white near the top, and the thermometer in the cover may shew scarcely 150° C. in badly constructed apparatuses. This signifies great differences in temperature, for polished steel becomes yellow at 221°, blue at 280°, and grey at 330° C.

air is employed. It is nevertheless a fact that instruments which have been put into the sterilizers quite dry, are often covered with rust on being taken out. Cooling down after heating seems to strongly favour deposition of moisture; this unfortunate occurrence may possibly be avoided by providing for good ventilation in the apparatus (Poupinel).

On these grounds we do not believe that the use of hot air in the sterilization of instruments has any great practical value.

When steam is used for this purpose, the case is somewhat different. First of all it must be borne in mind that steam disinfects considerably more quickly than hot air, and therefore an exposure of 15-20 minutes is sufficient. Again owing to the wide use of steam sterilization for dressings, a steam sterilizer is in the possession of most operators and numerous practitioners, and the extension of its application to instruments is convenient. Not a few surgeons, who use this method, find it satisfactory.

On closer examination, however, convenience is its principal recommendation.

First of all it is a great defect, that instruments very easily rust in steam. Nickel-plated instruments are protected to some extent, but unplated ones are usually covered with a thick layer of rust, and are so rendered useless. But the chief disadvantage of the steam, as of the hot air process consists, in its clumsiness and slowness. If sterilization in current steam be reckoned to take 20 minutes, and if by a suitable apparatus steam be rapidly developed, the whole duration of the procedure can be reduced to 30 or 40 minutes, even this would be as a rule much too long. Procedures, which are an essential part in the preparation for every opera-

tion, and for each one of a series of operations, could not far exceed a quarter of an hour in duration, without becoming inconvenient to surgeon and patient. Setting a steam sterilizer in action would only be of advantage in certain operations, as it is too complicated and also too expensive. This combined disinfection of instruments and sterilization of dressings should only be extended to laparotomies and major resections; in the case of small operations, which nevertheless demand just as great aseptic precautions, some simpler method becomes necessary. There is the same objection to steam as to hot air; that all instruments must be prepared once for all before the operation is begun, and if an instrument should, during the operation, be in any way contaminated, it cannot be sterilized by steam or by hot air as quickly as is necessary.

Steam under tension has a higher sterilizing power than current steam. The former was recommended by Redard (1889) for disinfecting instruments, and with this object he constructed a small autoclave. The heating of the autoclave takes a quarter of an hour, according to Redard, and the whole process of disinfection, which is accomplished at 110° C., he estimates at three-quarters of an hour. Disinfection in this apparatus may be very thorough when properly used, but the practitioner needs simpler methods, as we have maintained from the first. The regulation of an autoclave with thermometer and manometer is too complicated for ordinary use, especially as is well known, in small autoclaves, slight errors in heating produce superheating of the steam, or of some air remaining inside, instead of a higher tension, and so a diminution of the power of disinfection. But quite apart from this, it would appear a questionable procedure to leave, as is

usually necessary, such a high tension apparatus to assistants, for the danger of their exploding is only avoided by the control of an expert. Moreover the objections to other steam sterilizers hold good against this apparatus, for the purpose of sterilizing instruments.

If for the above mentioned practical reasons, exception be taken to the use of hot air and steam for this purpose, our last resort is to sterilize them by boiling water or some other fluid. Very different fluids have been proposed for this purpose besides water. Miquel (1890), for instance, used glycerine heated to 140° C., while Tripier and Arloing in Lyons sterilize their instruments in hot oil. Redard states, that boiling glycerine gives off an unbearable smell, and cannot therefore be employed, and fat is not desirable for sterilizing, since it only too readily provides a protective covering for micro-organisms, as has already been mentioned. Besides this sterilizing with oil requires accurate apparatus for regulating the temperature, and is on that account alone too complicated.

The case is different when boiling water is used. Boiling water is an excellant disinfectant, and in rapidity and power is better than steam, and can be procured in a few minutes. It is idle to ask to whom the credit is due of having introduced the practice of sterilizing instruments in boiling water. Individual practitioners had already practiced it, before there was as yet a science of bacteriology to explain the value of the method. Our thanks are without doubt due to Davidsohn for the first detailed estimation, and scientific proof of its value, in a work from Koch's laboratory. Davidsohn lays great stress on the extraordinarily favourable results of boiling, and establishes the fact, that

boiling instruments for five minutes is usually quite sufficient for disinfection. If steel instruments are boiled in ordinary water, they rust, they are often either thickly covered with rust, or else they show only small black spots; if the instruments are laid in cold water, and this is then boiled up, they are always very rusty; if they are boiled in water, which has already boiled for some time, they usually remain unhurt. It has long been known, and it is also stated by Davidsohn, that rusting of instruments can be guarded against by the addition of alkalies to the water.

Different alkaline salts have been employed for this purpose, chalk, common salt, caustic soda: and an addition of chloride of calcium has been found serviceable by Redard. But the simplest and most efficient is an alkali, which has been used for many years to clean instruments after use in von Bergmann's Clinic, and which has long been in use for household purposes, the ordinary washing soda. A solution of one per cent. of soda (carbonate of sodium $Na_2CO_3,10H_2O$) is fully sufficient to guard against any rusting of steel instruments, as has been determined by the author. The addition of soda does not at all decrease the sterilizing power of boiling water, as shown by bacteriological investigations; it rather increases it, because the dissolving and penetrating power of the alkali is added to the germicidal power of the boiling water. It may fairly be said that boiling soda solution represents the most powerful germicidal agent that we know and can make practical use of. The author has again and again made experiments, in which pieces of silk or thic woolen threads were impregnated with pus, pure cultivations of staphylococcus pyogenes aureus, bacillus pyocyaneus, and spores of anthrax, and were then

dipped for longer or shorter periods in boiling soda solution. The uniform result was that pus as well as staphylococci, and bacilli pyocyanei were killed in two to three seconds, whilst anthrax spores, which in some cases had still retained their vitality after twelve minutes in steam at 100° C. and were therefore extremely resistant, were completely killed after two minutes. An immersion of the instruments for several seconds would therefore be quite sufficient, in order to kill the pyogenic germs on them, and boiling for five minutes in soda solution would satisfy all claims in practice.

The great disinfectant value of hot alkaline solution is clearly shown by experiments of Behring on the washing soda used in ordinary laundry work. This soda solution has as a rule a temperature of 80°-85° C., as it is usually employed in washing linen, and Behring found to his surprise, that even at this temperature, considerably below the boiling point, the disinfectant power is quite extraordinary. Very resistant anthrax spores were killed by hot soda solution at 85° C., often in four, but certainly in eight to ten minutes.

It is moreover interesting, that according to Behring's investigations, the usual washing solution has a strength of about 1·4 per cent. of soda; a degree of concentration which is almost the same as that recommended by the author for sterilizing instruments. The ground on which hot soda solution is used in cleaning linen, and for other household purposes, namely that it dissolves and removes fat and dirt, applies equally to the sterilization of surgical instruments, and is a recommendation for the wide use of it for this purpose.

Quickness and certainty in its germicidal action are moreover not the only advantages of soda. Its simpli-

city and convenience are also of great value. If it is important in surgical practice to be able to improvise one's appliances, what could be more commonly available than fire, water, some soda, and a vessel for boiling, which are all that is required for the most efficient sterilization devisable for our instruments. When in a private house a few instruments, scissors, forceps, &c., have to be sterilized for a change of dressings, it is certainly more rational to immerse them for a few minutes in a pot of boiling water to which soda has been added, than to use carbolic acid, which is expensive and must be procured from a druggist. While as to disinfectant energy there is no comparison to be made between the two. But even major operations can be carried out conveniently with no more complicated apparatus. The instruments are laid in a clean vessel, water if possible already warmed is poured in until the instruments are covered by it, about a tablespoonful of powdered soda is added to the litre of water, and the vessel is then placed on the fire. In a few minutes, whilst the other preparations have been made, the instruments have been sufficiently boiled, the vessel with the instruments is then cooled down by placing it in a basin of cold water. The instruments can then be taken out of the vessel during the operation, with complete confidence in the precautions that have been taken.

After making use of this method for some time one begins to be dissatisfied with the common saucepan, and to look around for a more convenient apparatus. The apparatus (fig. 4), which is here described and represented, is used in the great operating theatre of von Bergmann's clinic, and has received its present form after numerous modifications and practical experiments by the author.

In its construction rapid heating has been the chief object aimed at. A mantle has been put over the boiler with the object of further making use of the hot gases. If gas be used the burner should have several coils ; if spirit be used there may be one large or several small flames. Care is further taken that the cover fits closely.

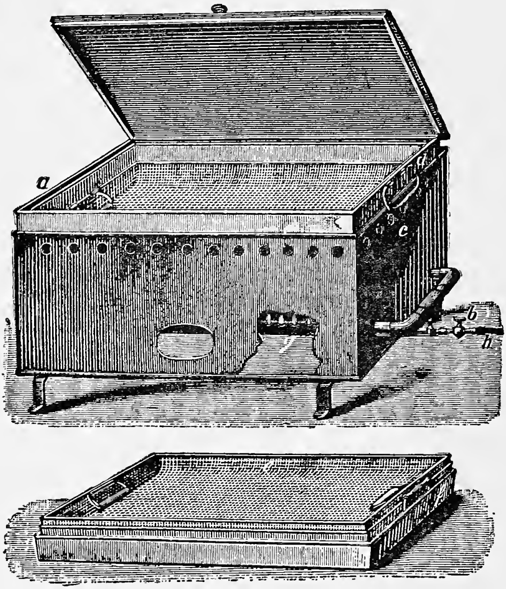

FIG. 4.—Apparatus for sterilizing metal instruments with soda solution.

Koch* has referred to the fact that water, boiling in an open vessel, has not the same temperature throughout. There is a considerable difference between the temperature of the surface and the deeper parts. In order to avoid this a closely fitting cover is necessary. The one per cent. boiling soda solution has a temperature of

* Mittheilungen aus dem Kaiserlichen Gesundheitsamt, Bd. I.

104° C. in a well closed boiling apparatus. If the cover is opened, the temperature sinks very soon, without ebullition stopping, to 93°-95° C. on the surface. In a larger apparatus it is a good plan to apply a closed water receptacle (*a*), firstly because it closes best, and secondly, because it seems to prevent the evaporation of the soda solution and so saves the trouble of refilling, an important consideration when the apparatus has to be in use for a long time. For this latter reason a gas tap (*h*), which can be turned in three directions, is fitted to the heating pipe. In the different positions of the tap the flame burns full, or low, or is turned out; and so the soda solution can be kept boiling or just warm. A well constructed apparatus should bring water at the temperature of the room up to the boiling point in five to six minutes. If gas is used this can easily be done by a sufficiently large heating coil, if only a high enough pressure is available. Spirit presents greater difficulties. With spirit flames of great heating power, the danger of explosion is difficult to avoid, without complicated devices. The supply of spirit must be from the side, as in the old oil lamps, in order to prevent its heating. When spirit must be used, for instance in private houses, a smaller lamp is sufficient, if the apparatus is filled with hot water first, and this will usually be obtainable under those circumstances.

An apparatus, which I have constructed for use in private houses, and which can be used at the same time for sterilizing dressings (cf. Chap. VII.) is shown in figures 5 and 6.

Any whitesmith can easily make it. It consists of a rectangular tin case, with a cover opening on hinges. The case is ten to twelve cms. deep, about fifteen to to twenty cms. broad, and twenty to forty cms. long,

according to the length of the instruments it is intended for. There are four removable legs fitted to it, sliding into slots on the long side. The spirit lamp as well as the instruments can be packed away inside the apparatus for transit. For use it is filled with hot water and a spoonful of soda, and either placed directly on a cooking

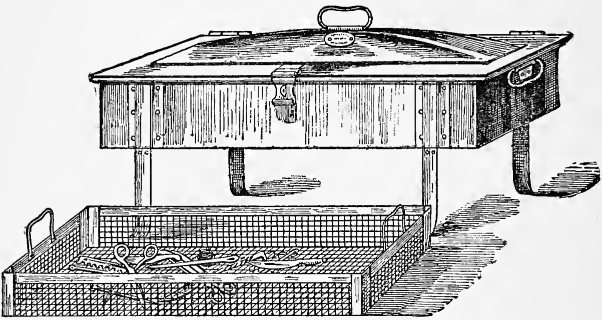

FIG. 5.—Portable boiling apparatus for instruments to be used on an ordinary fire or with spirit.

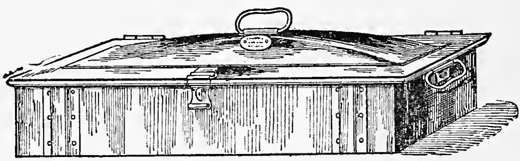

FIG. 6.

stove, or after adjusting the legs over a spirit lamp. A shallow Berzelius lamp is the best.

Wire baskets (*e*) are used to facilitate the immersion and removal of the instruments.

If small instruments have been boiled for five minutes in the soda solution, they rapidly cool in the air after removal, and can be used for the operation in a few

minutes. Larger instruments, for example, thick forceps and chisels take longer, and to expedite matters, and because on other grounds it is convenient not to have one's instruments dry during the operation, but lying in some fluid, the wire baskets, in which the instruments are boiled, are placed with the instruments in dishes, such as were formerly used for keeping instruments in carbolic. These dishes are conveniently made of such a size that they can be put into the vessel and boiled. They are filled with cold boiled soda solution, with the addition, if it is preferred, of any disinfectant agent, such as alcohol, carbolic acid, &c. In pure carbolic lotion instruments rust very readily, but there is no objection to a mixture of carbolic acid and soda, *i.e.*, carbonate of sodium, and for this purpose a solution of one per cent. soda and one per cent. carbolic acid is recommended.

It is of course unnecessary, to combine with this immersion any other disinfectant measures, for after boiling the instruments are quite sterile.

The apparatus is best made of copper or nickel. Sheet iron is less durable. The apparatus should not be too large, or it will be cumbersome.

The depth of the boiler need not be more than ten cms. In its other dimensions it is made in three sizes, according to requirements 45×30, 45×20, and 25×15 cms.

In an operating theatre, sterilized soda solution may be kept ready made for laying the instruments in during an operation, but in private practice it is better to prepare it fresh each time. For this purpose we have had made a vessel for powdered soda, in which there is a spoon, which holds exactly 10 c.cms., a spoonful is added to a litre of water in the boiling apparatus. A complete

and convenient set of utensils for sterilizing with soda is shown in fig. 7. On a small shelf stands the box (*a*) with the powdered soda and the spoon. Underneath hangs a litre measure (*b*), a box of matches (*c*), and in front a five minute sand glass (*d*) is fixed. Compressed soda tablets are made, of which a certain number are required according to the size of the apparatus.

Of all sterilizing processes, sterilization with soda damages metal instruments least. Even knives can be boiled, without losing their edge, as has lately been observed, if precautions are taken to prevent their moving about in the boiling alkali. Knives are blunted

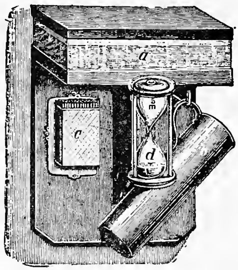

FIG. 7.—Box to hold soda, sand glass and measure for use with the instrument sterilizer.

when they are boiled only if the edge is knocked against the walls of the vessel, the wire basket, or other instruments by the ebullition of the fluid. Knives and all other cutting instruments must be laid in close fitting racks when they are boiled.

Directions for the sterilization of instruments may therefore be laid down as follows:—

1. Metal instruments are placed in wire baskets and, shortly before the operation, boiled for five minutes in a one per cent. solution of soda.

2. The instruments are taken out of the soda solution by means of wire baskets and put into dishes, which have also been boiled in the soda solution, and have been filled with cold boiled soda solution, or else a solution of carbolic and soda (aâ one per cent.).

3. During the operation soiled instruments, which are to be used again during the same operation, are rinsed with cold water and are again placed in the boiling soda solution.

4. After use the instruments are rinsed in cold water. They are then laid for some time in a hot solution of soda and soft soap and scrubbed; finally they are carefully dried and cleaned with alcohol and a piece of leather.

The energy of these measures and the exposure to damp heat involved in them, make demands on the instruments, which old fashioned tools cannot fulfil. The wood, horn, and caoutchouc handles to knives, sharp spoons, &c., which were formerly so much in favour, cannot stand the treatment, they have therefore given place to the convenient metal handles of modern make. A preference for light horn handles or heavy metal ones is merely a question of habit; such preferences must have no place where the necessities of asepticism are involved. If on emergency old instruments with horn and wood handles have to be used, it may be observed that those which are rivetted and not cemented, stand repeated boiling very well, only daily and prolonged heating damages them. All merely ornamental devices on instruments, the serpents of Æsculapius and embossed lion's head, which formerly delighted the eye of the surgeon, modern asepticism shudders at; while every endeavour on the part of the makers to simplify surgical tools, and so to facilitate

the cleaning of them, wins immediate recognition and support.

Nickel plated instruments have not by any means the great value usually ascribed to them. Nickel plating certainly limits the troublesome rusting of instruments, which are laid in carbolic or sterilized in steam, but it does not stand prolonged use without constant re-plating. Every fresh plating is less durable and chips off more easily than the last, till finally the instruments are completely spoiled. Nickel plating, or better still silver plating, answers very well for instruments, which are used only on special and rare occasions, since it protects them from atmospheric influences.

Instruments in daily use, since we have learnt to avoid rusting by the soda process of sterilization, no longer require nickel plating, all that is required for their preservation is attention to the directions, which have been given above as to cleaning and polishing, careful drying before they are put away being of course of the greatest importance. Much depends upon the assistant's attention to this point. Instruments, which have once rusted always remain liable to the formation of rust, even if they have been well cleaned.

Aluminium instruments, according to repeated experiments that we have made, are useless. The metal is too soft and is almost less resistant than horn and wood against disinfecting processes. Soda and strong soap lye, for example, partially dissolve it. A small aluminium instrument lost one-ninth of its weight, in one of our experiments, from five minutes boiling in one per cent. soda solution.

The cases or cupboards for instruments are to be so constructed, that they are easy to clean. Glass and iron are the best materials for cupboards, and tin for

cases to be made of. The instruments lie in cupboards on glass plates, in boxes in metal grooves, or between layers of sterilized wool. Paste board and leather boxes with velvet linings and leather pockets are relics of the past. Pockets made of canvas, however, which allows sterilization in steam, are permissible.

CHAPTER VII.

Aseptic Dressings.

The open treatment of wounds—The complete closure of wounds with impermeable coverings—The importance of absorbent powers in a dressing—Different dressing materials—An estimate of their merits—The dressing must be free from germs—Disadvantages of employing chemical agents for the disinfection of dressings—Disinfection by steam—The advantages of this method—Sterilization of dressings in private and in hospital practice—The importance of keeping dressings in closed boxes—Antiseptic properties of dressings—The importance of keeping wounds dry—The shortcomings of impregnated antiseptic dressings—The advantages of simple dry sterilized dressings—Plugging of wounds—Iodoform gauze—The advantages of dressings prepared by the surgeon himself—The uses of manufactured dressings.

Although we now know that wounds run no special risks of being infected by air free from dust, even after being exposed to it for hours during the operation, we shall not at once be induced to return to the so-called open treatment of wounds, and to leave them without any covering. We cannot prevent dust and dirt from being stirred up in the vicinity of a patient for very long, still less can we guard for any length of time against contact with infectious material. The open treatment of wounds, introduced into practice by Kern, before the days of antiseptics even, yielded more favourable results than any plan resorted to up to that time. While most operators found that more than half their amputations were fatal, Burow had a mortality of

7·5 per cent. in 94 cases of major amputations treated by the open method without any dressing. It was safer to cover a wound with nothing at all, than with the usual dressings, which were sure to be rich in germs of infection, in spite of the fact that during the long time necessary for such wounds to heal, dust and dirt often collected upon them to an alarming extent, and maggots were not uncommonly to be seen in them. But now-a-days we can, by means of an aseptic dressing, avoid with certainty the dangers of infection, which threaten a wound after the operation. It is only in the case of small superficial wounds, that it is justifiable to dispense with a protective dressing, which is free from germs: in such cases we may leave the wound to nature and sufficient protection is afforded by the dried secretions and the scab which soon forms.

The treatment of wounds by constant irrigation, or by immersion in baths till healing is effected is now one of merely historical interest. Either plan causes irritation of the wound surface, and maceration of the skin, and is from the aseptic point of view objectionable. The addition of strong antiseptics to the bath or to the irrigating fluid involves the risk of absorption by the wound or by the eczematous skin, which may end by poisoning the patient; while the weaker antiseptics do not prevent the development of infectious germs.

An aseptic dressing now-a-days must effect three things; it must:—

1. Absorb the secretions of the wound thoroughly;

2. Be itself free from pathogenic germs;

3. Act antiseptically, so as to prevent decomposition of the secretions absorbed.

The best means of protecting a wound from the dangers that threaten from without, might *a priori*

appear to be, to close it up as closely and firmly as possible. A completely impermeable dressing was one of Lister's ideas.

The dressing, which he at first made use of to effect his object, was a kind of putty made of common whitening (carbonate of calcium) and linseed oil, such as glaziers use, to which carbolic acid was added; this was laid over the wound smoothly and closely and was covered with a piece of sheet block tin. There are cases for which an impermeable dressing is still appropriate. Clean cut flesh wounds, the surfaces of which can be brought accurately together in the deeper parts no less than the superficial, such as skin incisions and sword cuts in the face, lend themselves to this simple mode of treatment very well. In these cases the line of suture can be covered with some unirritating strapping, or collodion or photoxylin may be painted on either directly or over a piece of gauze. These latter are more elastic and exert less pressure on the edges of the wound than strapping. But either plan will probably be preferred now-a-days to the use of putty and tin foil. Cases, in which healing would take place under a scab, or more correctly under a crust of quickly drying blood, are well adapted to this mode of treatment. The artificial covering provided by strapping or photoxylin adheres more firmly than a natural scab or crust, which is only too easily rubbed off.

But the number of wounds, that can be so treated, must always remain very small, for success is possible only when there is practically no secretion from the wound. If the wound secretes only a moderate amount of fluid, sealing is futile and even dangerous. The secretion, which consists of blood or lymph exuded after the dressing is applied, collects under the imper-

meable covering, breaks through the weak spots in the covering, and soon decomposes. The conditions are thus rendered less favourable than if the wound had not been dressed at all. If we wish to protect a secreting wound, and most wounds do secrete, the first essential is that the dressing should be capable of absorbing fully and completely all the exudations from the wound.

Lister very soon recognized this, and chose a material, hygroscopic gauze, which is still the type of what a dressing should be. Although very soon after its introduction attempts were, and still from time to time are made to find substitutes for it, these do not imply that anything better could be devised, but are evoked merely by considerations of economy. Expense is the only objection to gauze.

All the materials which have been proposed to take the place of gauze from blotting paper and moss down to ashes, sand and earth, are distinctly inferior to it in their powers of absorption. For covering and plugging wounds gauze is indispensable. Nothing is suitable for this purpose, which does not hold together in one piece like a woven material; particles will otherwise be left in the wound, irritate its surfaces, and delay healing. All the powdery substances, proposed for dressings, fail in this way conspicuously. Even cotton-wool, though it has its uses and is much in favour, is not suitable for placing next a wound, for when it dries, it sticks fast and cannot be separated from the surfaces of the wound. Loose powdery substances can only be used, as a rule, when they have been sewn into small bags of gauze, before being laid on.

The theoretical and experimental estimation of the absorbent powers of a dressing presents considerable

difficulties; so many practical considerations enter into the calculation, that it is best to let practice, that is its behaviour on the wounds, decide. In any case, a high power of absorption by itself does not determine the value of a dressing. Neuber, Fehleisen, Walther and Rönnberg have estimated the absorbent powers of different dressings by moistening ten grammes of the substance, until it was quite saturated and would hold no more fluid, and then weighing it. Rönnberg shews in the following table the results of his investigations.

10 grammes of saturated:—

1.	Wool free from fat (absorbent wool)	weighs	250	grammes.
2.	Cellulose wadding	,,	230	,,
3.	Wood wool wadding	,,	150	,,
4.	Wood wool	,,	106	,,
5.	Gauze	,,	96	,,
6.	Turf moss	,,	82	,,
7.	Poplar sawdust	,,	73	,,
8.	Jute	,,	70	,,
9.	Pine sawdust	,,	53	,,
10.	Coal ashes	,,	21	,,

According to Neuber, cotton-wool will absorb about three times as much water as gauze, according to Fehleisen from fifty per cent. to 100 per cent. more; in Rönnberg's table too, it stands at the head of the list, and yet common experience shews that cotton-wool will take up much less of the secretion from wounds than gauze.

The amount of fluid, which diffuses into a substance, which is merely brought into contact with the fluid, is equally valueless as a means of determining its merits as a dressing. The following experiments are of interest. A number of glass cylinders were filled with different substances used for dressing wounds; an equal degree of compression was secured by exposing the

substances to the pressure of the same weight in each case; the lower ends of the glass cylinders were then immersed to an equal depth in water or blood. The different levels to which the fluid rose in the different substances tested, were taken to indicate the absorbent powers of those substances. Rönnberg, using cylinders of 4·5 cms. in diameter, and compressing the substances tested with a pressure of 500 grammes, obtained the following results:—

In the case of	Coal ashes	the fluid rose	to the height of	6·4	cms.
,,	Cellulose wadding	,,	,,	4·6	,,
,,	Moistened turf moss	,,	,,	4·0	,,
,,	Sawdust	,,	,,	4·0	,,
,,	Wood wool wadding	,,	,,	3·6	,,
,,	Charpie	,,	,,	3·3	,,
,,	Dressing wool (absorbent wool)		,,	2·9	,,
,,	Sea sand and Asbestos in fine flakes	,,	,,	2·7	,,

Jute, tow, dry turf, and chopped straw, tested in this way, hardly absorbed any fluid. The substance, which according to this table gives the best results, is admittedly quite useless as a dressing.

Experiments would be valuable, which determined the amount of fluid that different substances would soak up, and allow to evaporate through them, in a given time. It is not required of dressings that they should absorb as much fluid in as short a time as possible, but rather that the process of absorption should be continued as long as the dressing is in use, the fluid evaporating as it is absorbed. Many substances, which rapidly and quickly take up large quantities of fluid, such as blotting paper, silk charpie, and cellulose wadding, are nevertheless quite unsuitable for dressings, for when once they are saturated, all absorption comes to

an end. They become soft, contract together and form a firm impenetrable layer like paste.

Many other points must be taken into consideration; the rapidity with which a substance absorbs fluids is of importance when it is used for sponging; changes in volume or elasticity when moistened, must also be taken into account.

The experience gained by the work of the last ten years goes to show, that next to gauze, moss is the best dressing. It makes no difference whether turf moss or wood moss is used, the moss is simply washed with water and dried, it is either sewn up in gauze bags, or used in the form known as moss felt (Leisrink), which is prepared from the damp moss by compression. Moss is very cheap, soft, flexible, and absorbs freely. In elasticity too, where pressure must be maintained or support given, it is superior to cotton-wool. Cotton-wool makes so soft and flexible a dressing, and is so simple and convenient, that it must be reluctantly abandoned only because of its small powers of absorption.

Preparations of wood, wood fibre, wood wool, and sawdust, come next after moss and cotton-wool in point of utility for dressing purposes. Their power of absorbing discharges is very much inferior to that of moss. Turf dust is remarkable among powdery dressings for its great powers of absorption. All the other materials, which have been tried, such as sand, ashes, tan, tow, bran, chopped straw, &c., have little to recommend them for general use, but on emergency, in military practice for instance, they might be resorted to.

The first thing required of a dressing in aseptic surgery is that it should be free from pathogenic germs. After what has been said in earlier chapters, it would be hardly necessary to lay stress on this, but that the

recognition of the great importance of simultaneous absorption and evaporation at one time led to the idea in some quarters that, compared with these properties, freedom from germs might almost be regarded as superfluous in a dressing. The effectual removal of secretions from the surface of a wound is certainly one of the most essential and important points in the treatment of the wound: a dressing which fails in this is at once excluded from consideration. But that the dressings must be free from germs is one of the axioms upon which the whole practice of aseptic surgery rests. It is quite true, as Volkmann puts it, that the human body is not like a test-tube of agar-agar or coagulated blood serum: contact with infectious material does not inevitably result in infection. But as long as the conditions, which determine the event of infection on the part of the body infected, and on the part of the microbes which cause the infection, remain as unknown as they are at present, and as long as there are germs like the streptococci of erysipelas, which can infect the human body from the most superficial and trivial wounds, as certainly as they can gelatine or serum in a test-tube, so long will it be the rule, not without exceptions it is true, for the omission of a careful disinfection of dressings to be visited with terrible, often the most terrible, vengeance. It must be accepted as a first principle, that materials, which are to absorb secretions from wounds, must be rendered free from pathogenic germs before they are used. Whether the same degree of freedom from germs should be exacted in the case of splints and the materials used to pad them, may be disputed; but even here we must not make too many concessions to convenience at the cost of safety. We should shrink from using for a compound fracture a

splint that was last used in the treatment of phlegmonous erysipelas, without thorough disinfection. In von Bergmann's Clinic, pasteboard and wood shavings are used for splints by preference, and are destroyed after use, mainly on aseptic grounds.

Upon the same grounds dressings should be selected of materials, which from the first are as free from germs as possible, and which can be easily sterilized; those rich in germs being as studiously avoided. Hewson's proposal, that earth should be used as a dressing, is irrational, since earth usually contains tetanus spores. A great advance has been made since specially manufactured dressings have come into use, which enable us to do without charpie—a product of domestic industry or of convict labour. The raw dressings as delivered by the manufacturers are much freer from germs than the shredded linen which was prepared often under very dirty conditions, and at any rate had passed through an unknown number of hands before it reached the surgeon.

Till recently it has been customary, after a more or less thorough preparatory cleansing, to disinfect the dressings by impregnating them with some antiseptic. Two ends were thought to be attained by these means; the dressing was freed from germs, and invested with antiseptic properties at the same time. With the second of these we shall deal later. Here we shall only repeat that freedom from germs is not so easily obtained by simply soaking in an antiseptic fluid, as used to be imagined. Now we know that the action of a disinfectant solution must last some time, often for days, in order to kill resistant spores with certainty, and that even then it may fail, when the bacteria are encased in grease and albumen which are difficult to penetrate.

By careful preparation, however, and long continued impregnation with powerful antiseptics, we can make absolutely certain of our dressings. Another objection to this plan for preparing dressings is much more weighty. After an effectual sterilization by this process, they have to be submitted to many unavoidable manipulations, such as wringing, drying, cutting, and packing. The disinfection in fact is not the last but the first step in the preparation; the dressing, after being disinfected in the antiseptic solution, has to pass through a dozen different hands before it is finally ready. If the trained eye of the surgeon watches over each of the workmen, the result may still be passable, but it will be very different in factories, where the purpose of the manipulations is not properly understood even by the managers, and where the inspiring motives are other than surgical.

This defect explains how it was that Schlange and other investigators after him found that antiseptic dressings which had been procured from various apothecaries' shops and factories, and tested bacteriologically, contained many germs, and that only the army dressings, prepared very exactly and under control, proved themselves to be free from germs (Löffler).

But after the purchased dressings get into the hands of the surgeon, manipulations begin afresh. The packets are opened, the materials spread out, cut to the right size, and packed away in dressing cases. It is easy to see that dressings so dealt with have to surmount a whole series of risks of infection before they arrive at their destination, the patient's wound.

All these sources of error can be easily avoided by the use of heat for the sterilization of dressings, especially in the form of steam. Hot air cannot be used for

this purpose, because the dressings are made brittle by it and spoilt. Hot water is excluded, as the dressings must be used and kept dry.

The great advantage of sterilizing dressings by steam over the old antiseptic dressings does not, however, consist only in the absolute certainty of their freedom from germs, and the rapidity with which this is effected; the extreme simplicity of the process makes it possible for it to be carried out frequently, if necessary every day, or just before each operation. The dressings can even be cut to the desired shape before being sterilized, so that they can be transferred straight from the sterilizer to the patient, and thus all but absolutely unavoidable manipulations after disinfection are avoided. The dressing is cut of the exact size and shape; bandages are rolled; wool is cut, and the layers of gauze arranged; all these are then placed in a tin box with a closely fitting lid, and sterilized in it with the lid open. Sterilization being finished, the box is closed, and the dressings are safe from contact with anything septic. The use of a dressing box, which can be firmly closed, we regard to be of considerable importance, and very much more secure than dressing cupboards and chests that cannot be disinfected.

As to the form in which the steam should be used—whether nascent, under pressure, or superheated—we have gradually been led to the conviction that simple nascent steam is quite sufficient for the sterilization of dressings as for most ordinary surgical purposes. For eight years all dressings in von Bergmann's clinic have been sterilized in nascent steam with the best results. To obtain a satisfactory result, the steam must be saturated, that is all air must be removed from the objects to be sterilized, and the steam thus enabled to

act quickly. Steaming in open vessels is irrational, the objects to be sterilized must be placed in a closed and covered space, the disinfecting chamber, into which the steam passes in such a way as to completely displace the air.

For sterilization on a small scale, the steaming vessel devised by Koch for laboratory purposes is quite sufficient. Koch's steaming vessel is cylindrical and made of tin; the lowest part is the water chamber holding several litres; a partition made of perforated metal, which forms the floor of the disinfecting chamber, is placed some inches above the level of the water; and the top is closed by a well fitting lid. The water having been brought to the boiling point, steam rises through the perforations in the floor of the upper chamber, upon which the objects to be sterilized are placed, drives the air out and escapes by lifting the lid. In an apparatus, made according to the dimensions given by Koch, when steam is up, the air is completely driven out, and no condensation occurs while the sterilizer is in use. But while steam is getting up, and when the dressings are introduced without being previously warmed, there is considerable condensation of steam which moistens the dressings. To prevent this in using Koch's sterilizer special precautions must be taken, or the dressings may be subsequently dried.

Many forms of apparatus have been made upon the same scale and the same principles as Koch's, which are all suitable for ordinary surgical purposes. To be of any use the apparatus must work quickly, develop steam energetically, and be portable. To obtain the full advantages of the steam process, boxes must be provided for the dressings which can be securely closed. A contrivance, by which the sterilization of instruments

in soda solution could be simultaneously carried out, would obviously be an additional convenience.

We need not here describe the numerous more or less similar forms of apparatus, which have been devised by Rotter, Straub, Braatz, Mehler, Kronacher, and others, of which we have no personal experience. A small sterilizing apparatus, which has been practically tested by the author, will alone be described, in the form which after years of use has been found most convenient.

Half the apparatus, serving for the sterilization of instruments, has already been described in an earlier chapter. The whole consists of a water tank, over which a rectangular case can be fitted, when the lid of the tank is opened upon the hinges with which it is provided (fig. 9).

This case (fig. 8) is for dressings or cloths, which are to be sterilised, boxes for the dressings, which can be closed (fig. 10), as well as a large wire basket for towels, coats, &c. The boxes for the dressings are made in two parts, one of which fits over the other.

The surgeon can easily keep in store a number of these dressing boxes of different sizes, filled and sterilized (figs. 11, 12 and 13).

The sterilization can be carried out in the apparatus described over an open fire as well as over spirit lamps or gas, since the instrument boiler, filled with soda solution, can be heated either way. The vapours of the boiling soda solution penetrate the dressings in the case and escape under the lid. It is imperative that the source of heat used should be sufficient to keep the soda solution in violent ebullition. The whole process lasts three-quarters of an hour.

The temperature of the steam has been frequently

tested and has been found to reach 100° C. in all parts of the disinfecting chamber; the boiling point of the soda solution being as high as 140° C., we have ad-

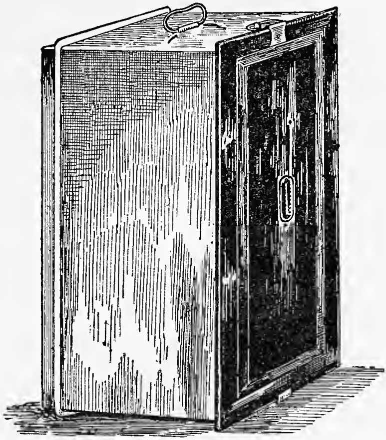

FIG. 8.—Case for the sterilization of dressings.

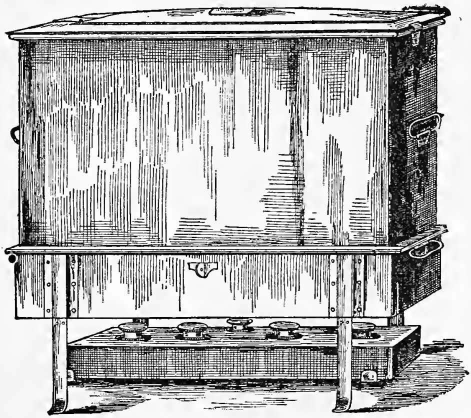

FIG. 9.—Combined apparatus for sterilizing dressings and instruments.

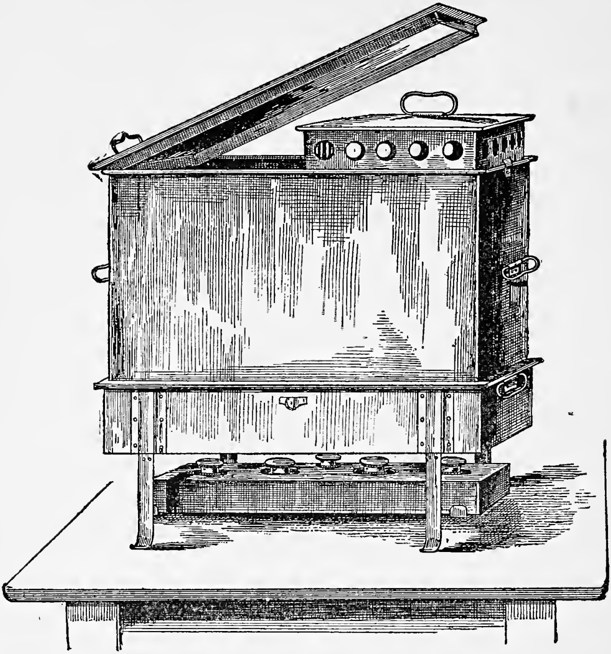

FIG. 10.—Sterilizer for dressings with the disinfecting chamber open ; a box for the dressings is being introduced.

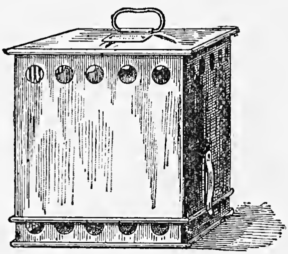

FIG. 11.—Dressing box opened.

ditional guarantee that this will be so. Experiments in disinfection with anthrax spores, and with dressings soaked in pus, always resulted in the complete destruction of the organisms after fifteen minutes. The whole apparatus is so simple that it can be put together by any whitesmith.

This apparatus is designed only for sterilization on a

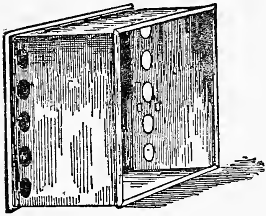

FIG. 12.—Cover of a dressing box.

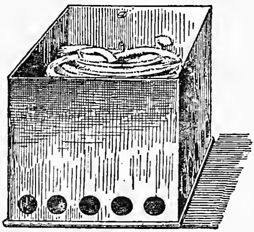

FIG. 13.—Dressing box without a cover.

small scale, and is of course inadequate where large quantities of dressings have to be disinfected. When constructed upon a larger scale, difficulties arise, which vary with the scale. The disinfecting chamber is not completely filled with saturated steam, the air in it and in the dressings being difficult to displace entirely.

One proposal for its improvement is that the disin-

fecting chamber be made air-tight, and the air in it exhausted before the disinfection begins and the steam is introduced, so that the steam no longer has to drive the air out. This may be desirable when the objects which have to be disinfected are very hard to penetrate, such as bales of cloth; for dressings it is unnecessary. Gauze, wool, bandages, and cloths are comparatively easily penetrated by steam, so that the results are arrived at by simpler arrangements.

It is desirable that in sterilizers upon a large scale, the following points should be attended to:—

1. The things to be sterilized should be warmed before steam is introduced.

2. The steam should enter the disinfecting chamber from above and not from below.

3. The pressure should be slightly raised.

4. The dressings after their disinfection is completed should be dried.

It was formerly thought that there was a danger of the steam not reaching the corners and angles of the disinfecting chamber. Frosch and Clarenbach have shown by careful investigations that this is not the case. Steam is distributed throughout all parts of the apparatus, if only every point of the chamber can be reached by a horizontal path. The shape of the apparatus may be cylindrical or rectangular without affecting the results, and in such recesses as are produced by putting in boxes, &c., the temperature rises just as quickly as in the rest of the chamber.

On the other hand, Gruber, Frosch and Clarenbach, Teuscher, and others, have all shown that it is a mistake in the larger forms of apparatus to allow the steam to enter the disinfecting chamber from below. In the first place, when the water chamber communicates

directly with the steam chamber, the dressings may be actually wetted by the bubbling up of water in violent ebullition. But they have also shown that the apparatus cannot be so satisfactorily saturated with steam when it is admitted from below. Air is heavier than steam, tends to sink below it, and is therefore less easily driven out of the steam chamber when the steam enters below and can get out of the top, than when it enters the apparatus from above, and lies at a higher level than the air, which can escape at the bottom of the sterilizing chamber. It is not till the chamber is filled with steam that the disinfecting action begins, and this action is more quickly and certainly effected when the steam enters at the highest point. Teuscher proved this in an apparatus made by Gebrüder Schmidt of Weimar. It was so constructed that the steam could be admitted either from above or from below. The experiments were made with bell thermometers on two blankets folded so as to measure 25×60 cms. On admitting steam from above a temperature of 100° C. was reached in seventeen minutes on an average; when steam was admitted from below, this temperature was not reached till after twenty-two minutes twenty seconds, that is fully five minutes later. He was also able to prove, as Pfuhl had already done before, that when steam enters from above, the steam slowly drives the air before it out of the apparatus, and that the level of the descending steam can be plainly felt on the cylinder outside. Steam begins to escape from the opening at the bottom only when the whole of the cylinder feels hot.

If steam is allowed to enter the apparatus from below, it begins to stream out at the top immediately and so shows that steam and air are irregularly mixed.

A slight increase of pressure in the apparatus

guarantees, in the first place, that the objects to be disinfected are more quickly and completely penetrated by the steam, and secondly that the temperature is uniform and condensation is avoided. An increase of pressure equivalent to one-fifth of an atmosphere corresponds with a steam temperature of about 102° C. This was the pressure obtained by B. Ritschel and Henneberg in their large steam sterilizers for hospitals and cities. Preliminary warming and subsequent drying of the articles to be disinfected are important in order to prevent or do away with moistening. Special arrangements for drying may be dispensed with when the preliminary warming is satisfactorily carried out. Steam freshly generated does not make things wet; when condensed by lowering of the temperature it does. Condensation occurs if hot steam is directed on to cold articles, and dressings become very much soaked if, when they are cold, they are brought into contact with hot steam in a cold steam chamber. Preliminary warming may be effected in the following manner. The disinfecting chamber has a double mantle, and the steam is directed through the intervening space, before it streams into the chamber. In arrangements for drying, hot air is directed over the objects after the disinfection has been completed.

The apparatus (fig. 14) by Lautenschläger has been in use for almost three years in von Bergmann's Clinic, supplies sterile dressings for the operations, and has proved itself to be thoroughly efficient. It consists (as shown in figs. 14 and 15) of two copper cylinders (M, N) placed one inside the other, which are surrounded by an asbestos jacket (A) varnished with locomotive varnish. Recently the outer jacket has been made of linoleum. The space (O) a few centimetres in width,

between the outer and inner copper cylinder, is filled to about the middle of the apparatus with water, the height of which can be read off by a guage. This water can be heated to boiling by a coiled burner.

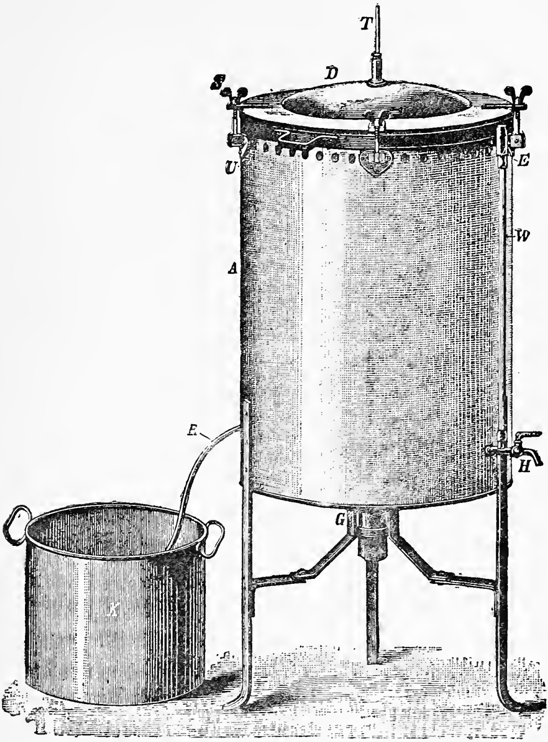

FIG. 14.—Steam sterilizer for dressings by Lautenschläger. Side view.

The steam ascends in the space O and passes through openings V at the upper end of the apparatus into the interior of the inner copper cylinder, which is intended for the reception of the dressings. The apparatus

being closed by the cover (D), the steam cannot escape upwards, but passes downwards in the direction of the arrows and leaves the sterilizing chamber by the tube (R). Hence it is conducted through the coils of

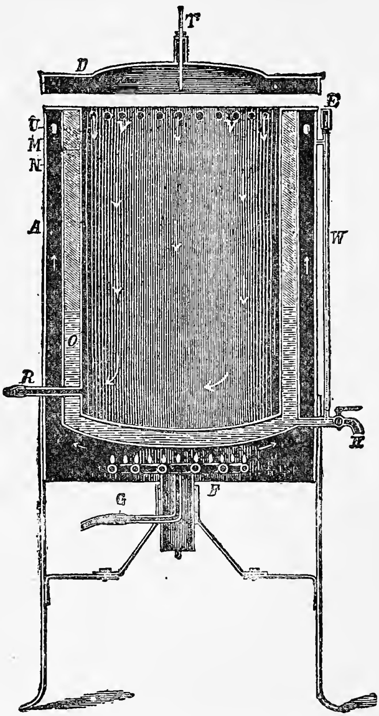

FIG. 15.—Steam sterilizer for dressings. Section.

a lead pipe and condensed in a cooling vessel with water. The cover (D) can be hermetically closed and is screwed tight by screws (S). A thermometer (T) is fixed in its centre. The apparatus is filled with water

through the water gauge (W) by means of a funnel at (E).

The water in the space (O) having been warmed by the heating coil, the interior and its contents are warmed before the production of any steam, and they are already heated when the steam comes into contact with them. The steam streams in above and out below. A well closing lid as well as the small calibre of the steam exit tube, which opens under water, guarantee a temperature of 100° C. and moreover a slight tension,

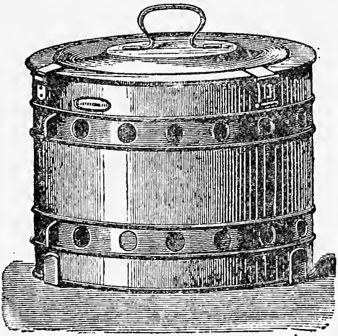

FIG. 16.—Dressing box, which can be closed, for sterilizing dressings in steam.

which amounts to about 26 mms., that is about $\frac{1}{30}$ of an atmosphere; we have convinced ourselves of this by several measurements. When the apparatus is filled and closed, and as soon as the thermometer indicates a temperature of 100° C. in the interior, the dressings are sterilized for three-quarters of an hour and then taken out sterile.

The vapours escaping from the apparatus can be simply caught and condensed in a cooling vessel, which stands near the apparatus. Where, however, tap water can be used to cool a coil, it is more advan-

tageous to condense the steam in a cooling coil and then either to conduct the distilled water back again into the space O, or to use it as sterile water for operative purposes (cf. Chap. XIII.).

The apparatus may be heated equally well with gas or spirit, and can be connected directly by means of conducting pipes on to a large steam boiler for larger hospital use, when steam is at one's disposal.

Round tin boxes (fig. 16) serve as receptacles for the dressings: these are placed in the sterilizer. There are no holes in the bottom and the lid fits closely. At the

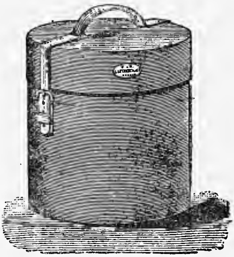

FIG. 17.—Dressing box in a leather case.

upper and lower margins of the sides are a row of holes, which can be closed by pressing the lid down closely.

The dressings, prepared ready for use, are placed in the boxes, which are put with the holes open into the sterilizer. With a powerful development of steam, the whole box is completely filled with steam in a quarter of an hour, even with fairly firm packing, as shown by experiments. The pieces of dressing are only slightly moistened after their sterilization is completed, since they have been well warmed beforehand in the apparatus. If the box is allowed to stand for a short time after it has been taken out, with the holes and the lid open, the dressings become quite dry. The lid is

then pushed down and the holes so closed. For transport in surgical practice outside a hospital, the boxes are conveniently placed in leather cases (fig. 17).

As to the time which is required to effect a thorough sterilization of the dressings, half an hour from the time when the apparatus is completely filled with steam should suffice, provided that the dressings are not so firmly packed as to make it very difficult for the steam to penetrate them. The time taken in filling the apparatus with steam, that is in starting the sterilization, depends partly upon the size of the apparatus, but principally upon the source of heat. On an average Lautenschläger's apparatus is completely filled with steam in less than a quarter of an hour from the time when the water begins to boil. The dressings may therefore be placed in the sterilizer, before it has been heated, the time when either the water begins to boil, steam is freely given off, or the thermometer registers 100°, is observed, then after three-quarters of an hour from this time the dressings can be taken out as sufficiently sterilized.

Thirdly, our dressings must have an antiseptic action, and as far as possible prevent the development of fission fungi in the secretion from the wound. This is especially necessary in the case of wounds that are infected to start with, but it also applies to quite fresh wounds, which have been produced under aseptic conditions. The secretion of a wound is such an excellent nutrient medium for germs, that even solitary organisms that reach the dressings soaked with secretion, would there multiply enormously if precautions were not taken to prevent it.

It was formerly believed that the safest way of imparting antiseptic properties to dressings was to im-

pregnate them with antiseptic agents. The dressings were dipped in the antiseptic fluid before being placed on the wound, and were then applied, after being wrung out perhaps, but still wet; or else the dressings impregnated with antiseptics were used dry, so that the task of dissolving the antiseptic devolved upon the secretions from the wound.

A great number of experiments have been made to test the value of these measures, with the result that in recent years there has been a growing conviction that a dressing which is absolutely dry, does more to check the growth of organisms than all the antiseptics that have been recommended for this purpose.

Nothing can be simpler, more innocent, or even more effectual in preventing decomposition than an absolutely dry dressing, which allows the discharges to evaporate. Moisture is the first requisite for the lower forms of life, drought their bitterest foe. The very best nutrient media known to bacteriologists, if deprived of the water in their composition, allow no growth to take place. And with a sealed dressing, if the blood, pus, and discharges of the wound are allowed to dry, the development of germs is put a stop to. For the appreciation of the importance of dry dressings, we are indebted to Esmarch and his pupils, especially Neuber. Schlange has demonstrated by very original experiments in Bergmann's Clinic, how promptly the drying up of moisture arrests the growth of fungi.

Schlange soaked layers of sterilized gauze with meat juice or broth, and inoculated the surface with bacillus pyocyaneus. The layers of gauze were then laid in glass dishes. If these dishes were left exposed to the air, free evaporation of the nutrient fluid in the gauze was able to take place, and the growth of the fungus

was local and limited. If the dishes were covered, so that evaporation was prevented, the bacilli proliferated quickly and very soon grew through the whole layer of gauze, colouring it green. If, on the other hand, after the fungus had penetrated some centimetres, the cover was removed and free evaporation allowed, the effects of evaporation quickly overtook the advancing growth as the nutrient medium got more thoroughly dried, and then further development was put a stop to. To promote the evaporation of secretions from the wound as much as possible, a suitable material must, in the first place, be chosen for the dressing, and secondly it must be so applied that evaporation is in no way hindered. Materials must be used, such as gauze and moss, which are not only capable of absorbing large quantities of wound discharges, but also give the water in their composition every opportunity for evaporation. Further, no impermeable material should be allowed to form any part of the dressing.

A proper use of evaporation has the inestimable advantage over dressings impregnated with antiseptics, that while it checks the growth of bacteria, it cannot hurt the patient. The use of antiseptics in a dressing is always a *remedium anceps;* small quantities of the antiseptic do not prevent the multiplication of germs, large quantities often cut both ways; they act prejudicially for the fungi, but also for the wound and patient. Without always causing severe general intoxication, their local effects are very important and troublesome. Severe local irritation is often set up in an unpleasant manner under antiseptic dressings, and increased discharge as well as eczema of the skin may often call in question all their advantages. It is not merely a matter of idiosyncrasy manifesting itself in

intolerance of the particular antiseptic present in the dressing; the measures taken in disinfecting the skin about a wound or in the field of operation, which must of necessity precede the application of the dressing, are in part responsible for the unpleasant result.

At any rate the efficacy of antiseptic substances in dressings has been much over-estimated. It must be remembered that we are endeavouring to prevent the growth of bacteria not in broth or water, but in albuminous fluids, which though certainly they do not entirely do away with the virtues of the chemical agents employed, nevertheless considerably modify them. Besides, that part of the dressing, which is in immediate contact with the wound, and through which all the discharges must pass, must quickly have all the antiseptic in it washed away, and so lose its special properties.

It has also been found very difficult to provide an antiseptic dressing in which the proportion of the antiseptic is constant, or will remain the same for any length of time. After a time the chemical compounds decompose, not only in dressings applied to a wound, but also in packets of dry and carefully kept dressings. Carbolic acid evaporates, for example, and sublimate changes into combinations which are quite ineffectual. In packets of sublimate gauze or wool which have been kept for one or two years, mere traces of the originally large proportion of sublimate have been found.

Finally impregnation can only be satisfactorily carried out by using resinous, or oily substances, or glycerine; otherwise the antiseptics, when they dry, shake out, and do not adhere. But unfortunately the use of these solvents diminishes the absorbent powers of the dressings, and so deprives them of a property, the importance of which we have just discussed in detail.

In von Bergmann's Clinic, whenever there is a reasonable hope that the dressings may become dry, nothing but absorbent sterilized gauze or moss has for years been used as a dressing, all impregnation with antiseptics has been done away with. Moist dressings covered with impermeable oil paper or gutta percha are before all things eschewed, hardly anything can be more favourable for the growth of organisms in the discharges. Besides which, it is almost impossible to leave these moist dressings on freely suppurating wounds for more than twenty-four hours without a strong smell becoming perceptible.

There are circumstances, however, in which the beneficent effect of drying the wound is not available, when either the discharge is very thick and tough and perhaps foul, or when there are cavities to be filled by plugging. A tough thick discharge is taken up with difficulty even by gauze, and will collect under the dressings, and in plugging cavities in a wound it is impossible to attain to perfect dryness in the deeper parts. It is under these conditions that it becomes imperative that antiseptic material should be used for the dressing where it is in contact with the wound, although in the more superficial parts we may effect enough by evaporation. For the development of antiseptic properties in plugs for wounds, neither sublimate, nor carbolic, nor salicylic acid, is suitable, nothing is better than iodoform.

Iodoform has kept its place among remedies used for dressings, and has so far proved indispensable to the surgeon. It has not suffered by the numerous attacks which have been made against its use in latter years. Although its capabilities have been much questioned by bacteriologists, there is no remedy which so certainly

prevents the decomposition of secretions in a plug, and at the same time irritates so little, and is so slightly toxic.

But iodoform gauze should not be prepared by impregnation with an ethereal solution, or with a glycerine emulsion. In the former process the iodoform easily decomposes, and iodine is liberated, in the latter the powers of absorption suffer. It is best merely to powder the iodoform into the gauze. Unfortunately, iodoform gauze so prepared cannot be sterilized in steam, which decomposes the iodoform. In von Bergmann's Clinic, iodoform gauze is prepared by sprinkling sterilized gauze with boiled water, powdering iodoform on to the

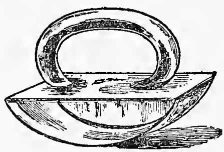

FIG. 18.—Flat iron made of glass.

gauze, rubbing it over with a sterilized gauze pad, and finally working it in with a sterilized flat iron—made of glass (fig. 18); it is then kept in a sterilized receptacle. For use on a small scale, it is best to sprinkle the iodoform over the sterilized gauze shortly before use, as it is required.

For wounds with a foul tenacious and purulent secretion, liquor aluminii acetici or chloride of zinc may often be used instead of iodoform with good effect. Acetate of aluminium is most conveniently used in three per cent., chloride of zinc in one per cent., solution in water, the gauze is dipped into the solution, wrung out, and laid in thin layers on the surface of the wound.

No impermeable material should be used with the dressing here either, but simply layers of dry gauze or moss.

Although sterilized dressings, prepared under the surgeon's own directions, are preferable to manufactured antiseptic dressings freed from germs, and should be made use of whenever circumstances permit, on the grounds of asepsis and economy alike, still prepared dressings cannot be entirely dispensed with. Prepared dressings free from germs have their uses when there is neither time nor any convenience for setting a sterilizing apparatus in action. But the surgeon should for safety be perfectly sure of his manufacturer, and be able to reckon on their being really free from germs.

It is of the first importance that such dressings should be packed so as to be safe from contact with infection. When there is any chance of exposure to weather or moisture in any form, which might wash micro-organisms through the wrapper to the dressings, tin-foil is of course the proper material for the envelope. But under ordinary conditions simple cheap paper, or cases made of card or parchment are sufficient. Before packets of prepared dressings are sterilized, the material must as far as possible be first of all cut to the right size, and then envelopes and contents are sterilized at the same time. After sterilization the packets must be closed without the contents being touched. This can easily be done in different ways.

CHAPTER VIII.

Aseptic Sutures and Ligatures.

The different materials used for this purpose—Disinfection of silk by boiling—von Bergmann's method of disinfecting silk by steam, and its advantages—The use of thread for sutures—The sterilization of metal wire—The sterilization of catgut—Lister's original process—Kocher's juniper catgut—von Bergmann's sublimate catgut—Disinfection of catgut by hot air—Disinfection in xylol by Brunner's method—The superiority of von Bergmann's method in sublimate—The manner in which catgut is absorbed in the living body, and the time necessary for this to take place.

A large number of materials were recommended and employed for sutures and ligatures in pre-antiseptic days. Formerly, when attempts were made to close wounds and ligature vessels without reaction, surgeons from ignorance of the real causes of suppuration and inflammation, thought that the secret of success lay in the material used, and were always adopting new ones. Now-a-days we know that the thread may be of any material or any colour, it may be smooth or it may be rough; perfect healing depends upon only one condition, the thread must be free from germs. Consequently we are now content with a few well established sutures and ligatures, and our endeavours are all concentrated upon their thorough disinfection. The materials we use are either:—

1. Such as are gradually dissolved by the tissues; or,

2. Such as are left to heal in, either permanently, or to be after a time removed.

What we call "catgut" belongs to the former cate-

gory, whilst silk and wire are practically the only materials which come under the second class.

Sterilization of silk is no difficult problem. Of course it is not sufficient to dip the thread for a few minutes in a disinfectant solution, as was at one time often presumed. For even if we were to use 5 per cent. carbolic acid and 1 per cent. sublimate, pathogenic spores and also bacilli and cocci could remain for days and weeks in such a fluid and continue capable of causing infection, if only they are coated with fat, albumen, or layers of dirt. We no longer venture to employ threads impregnated with some antiseptic dissolved in oil or other greasy material, since R. Koch has proved that an anti septic dissolved in an oil almost entirely loses its germicidal properties. The old-fashioned English process of preparing silk sutures by saturating the thread with a mixture of carbolic acid and liquefied wax (1 : 9) has rightly been generally abandoned.

For the sterilization of silk heat should be applied either by boiling or the steaming process. Disinfection by hot air, requiring an exposure of 3 hours to a temperature of 140°-150° C., is not only too complicated, but also damages the silk after repeated application by making it brittle. Disinfection by boiling is much practised, and many operators boil their silk before each operation. This can be done at the same time as the sterilization of the instruments, if the silk be wound on small glass or metal bobbins, and boiled for each operation with the instruments in soda solution (cf. Chap. VI.). Many surgeons boil their silk once for all for one to two hours in water or some antiseptic solution, and then keep it for use in five per cent. carbolic or one per cent sublimate. Glass vessels of many forms have been devised for keeping sterilized silk wound up on

glass reels in an antiseptic solution, from which the thread can be easily drawn out (cf. fig. 19).

Suture silk has been sterilized by steam, in von Bergmann's Clinic, in the following manner for years:—The threads are wound upon bobbins, placed in a small metal box, and are placed box and all into the steam sterilizer, at the same time as the dressings if desired, and left there for three-quarters of an hour. The silk, even if frequently so heated, is not spoilt. With a properly fitting box for the silk, the process need not be repeated for each operation; a single sterilization lasts for some time. This plan has considerable advantages; no antiseptic is used which can irritate the

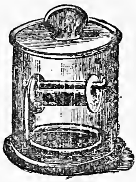

FIG. 19.—Glass vessel for keeping silk sutures in sublimate solution.

tissues, and the threads are dry, and therefore easier to thread and tie. Silk sterilized in steam is also easier to keep and carry about. The small apparatus represented here was introduced by the author; it is a modified and simple form of the box for silk sutures which has been used for a long time in von Bergmann's Clinic (figs. 20 and 21).

It consists of a box (fig. 20), one side of which can be raised (*b*), with a lid (*c*) the edges of which fit closely over the sides of the box. The reels for the silk run upon three small fixed rods, and can be easily rotated or taken out. The reels themselves are light, consisting

only of two discs bored with holes, and connected together by means of rods. By this arrangement steam gets ready access to all parts. Silk is wound upon these reels, and the ends of the threads are passed through slit-like openings (*a*, fig. 21). The apparatus

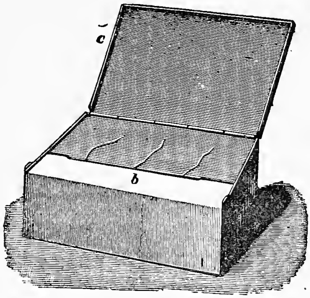

FIG. 20.—Box for silk suture for sterilization by steam.—Closed ready for use.

is put in the steam with the reels somewhat drawn out. On taking it out the cover (*b*) is closed, and so presses upon the threads as to prevent their slipping back during use.

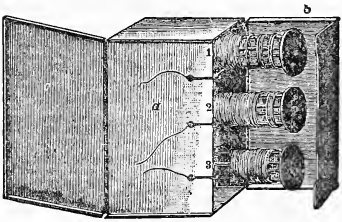

FIG. 21.—Box for silk suture for sterilization by steam.—Open for sterilization.

At the commencement of the century silk was not the form of suture most in favour, thread was very often used. Recently thread has been recommended for sutures by Heyder of Trendelenburg's Clinic.

Thread is considerably cheaper than silk, almost sixty times. There is also no doubt that thread can be as easily sterilized as silk, but opinions differ upon its convenience in use, and many surgeons after trying it have returned to silk, which is easier to work with and to tie.

Wire, which is so much used by some operators, but which in von Bergmann's Clinic is used only for fixing bones, can be sterilized very well by boiling shortly before use. To keep it free from germs, it may be put into absolute alcohol.

The search for some form of suture and ligature, which would be absorbed by the tissues, has long engaged the attention of surgeons. With this end in view, Dupuytren, A. Cooper and von Walther made experiments with threads of organic material, leather and intestine. In those days silk ligatures could never be relied on; instead of allowing them to heal in, the surgeon, for want of aseptic silk, had to wait for them to be cast off as the wound healed, and so ligatures that could be absorbed were specially desirable. The general practice then was not to cut the ligature short, but to let the ends hang out of the wound, so that it might be quickly and easily removed, after thrombosis had occurred in the ligatured vessel.

But even at the present day, a ligature that can be absorbed is an advantage. Although of course the tissues will usually heal over silk or wire, it is not uncommon for ligatures, after a wound has closed over them by first intention, to set up suppuration some time later and be cast off. The wound at first heals perfectly; then an abscess forms and after weeks or months a sinus leading down to the ligature, through which the silk which has caused the disturbance is finally discharged. Lister, for instance, in the extirpa-

tion of a goitre had occasion to tie six hempen ligatures; after the wound had healed by primary union, all the six ligatures were thrown off one after the other. Silk or wire that has healed in always remains as a foreign body in the tissues, of which the organism rids itself as soon as a suitable opportunity occurs.

The credit of having introduced the use of prepared gut in surgery belongs undoubtedly to Lister, for although Astley Cooper ligatured with catgut, the absorption of ligatures could only become practicable after the introduction of aseptic principles. It was Lister who first proved in practice the advantages of such ligatures, and gave directions for the antiseptic preparation of catgut. Lister's method of preparing catgut consisted in laying the commercial article in a mixture of carbolic acid (one part), olive oil (ten parts), with the addition of a little water, for a month. The addition of water made it possible for the oil to mix with the carbolic acid. Catgut so prepared was the first in the field and held it for a long time; afterwards it was given up by Lister himself. From the description, it is quite clear that in this mode of preparation there was little guarantee that the gut would be free from germs, and from many quarters complaints were made of cases of severe infection caused by it (Volkmann, Zweifel and others). Lister himself devised an improved method of preparation, in which chromic acid was used. The chromic acid was intended to give greater strength to the gut, and greater security to the knot when tied. According to this new process, the gut is laid in a five per cent. watery solution of carbolic acid, which contains chromic acid in the proportion of 1 : 4000. It remains in this solution for 48 hours, is then dried and kept in carbolic oil (1 : 5).

Very many methods of preparing catgut have been proposed in recent times; but the object of the more recent proposals is different from that of the earlier. All Lister's efforts and those of his immediate followers were, as we have mentioned above, concentrated upon procuring a harder form of gut, which when soaked in blood or serum would swell less readily; hence the use of chromic acid, and the long time, even months, taken in preparing the gut. We now know that this is not the danger, and with a moderate degree of hardening, such as can be easily attained by various methods, there is no fear of the gut swelling too much or of the knot being loosened. More and more importance has, on the other hand, been attached to a thorough disinfection of the gut. The difficulties presented by this, and the natural association of the gut with the bacteria of the intestine, have made many surgeons opposed to its use, and even led some to abandon it altogether.*

Catgut is not prepared, as the name implies, from the intestines of the cat, but from those of sheep. According to Lister, the small intestine of a sheep is first of all freed from its mesenteric attachment and washed in water; it is then prepared on a board by means of an instrument with a thick edge like the back of a knife. What is called by the workmen the "dirt" is removed by scraping the intestine with this instrument; this is

* For instance, Kocher of Bern and the Dorpat Clinic (J. Klemm, 1891). In both Clinics failures in asepsis were ascribed to the use of catgut. It must, however, be insisted that in neither case was the proof that the catgut was in fault forthcoming; the catgut in the Dorpat Clinic was even found to be free from germs. It must obviously be difficult, in the absence of direct proof, to say exactly where our precautions have failed, and how a wound became infected, when we consider how numerous the sources are from which failure in any one operation may arise.

nothing but the intestinal mucous membrane. The outer or muscular coat is scraped off in a similar manner, so that a thin tube, consisting only of the submucosa, remains (Halsted); this is blown out into the form of a pipe, the delicate structure being preserved in its entirety from end to end of the intestine. From this the cords are made, like hempen ropes, by twisting together either the whole intestinal tubes or strips cut from them, according to the thickness required. The cords so prepared are afterwards treated by manufacturers in various ways, with alkaline baths, solution of sublimate and bleaching agents, so that they are to a certain extent already disinfected. But the raw catgut, obtained from the factories, is nevertheless usually very rich in germs. It must be subjected in every case to a thorough process of disinfection, for it may contain not only innocent intestinal bacteria but also organisms that are pathogenic. The wide distribution of anthrax among sheep makes it likely that the gut might contain anthrax germs. Volkmann described two cases in which anthrax pustules occurred in fresh wounds, which had been sewn up with catgut. He is inclined to trace the infection in these cases to the catgut.

Disinfection, as we have shown, is not efficiently carried out by placing the gut in carbolic oil; but neither is the treatment with chromic and carbolic acid, which was the essential in Lister's later method of preparation and also in McEwen's, really adequate.

The use of juniper oil, according to Kocher, is more deserving of confidence. Kocher places the gut for 24 hours in juniper oil, and afterwards keeps it in 95 per cent. alcohol.

Von Bergmann has catgut treated with a one per

cent. solution of perchloride of mercury in 80 per cent. alcohol. The treatment lasts at least 48 hours, and preferably longer. The catgut is placed in the mixture of sublimate and alcohol, which at first becomes cloudy. It must be changed until it remains quite clear. The gut is afterwards kept in ordinary alcohol.

Experiments have lately been made with a view to making use of the high disinfecting powers of heat in the disinfection of catgut. For this purpose, steam and boiling water are quite out of the question; for after a few minutes in either, catgut swells up into a formless tangle, and is converted into glue. The addition of strongly corrosive substances to the water, such as sublimate, chromic or carbolic acid, makes no difference as the author's experiments show. On the other hand, hot air can be used for sterilizing catgut. Reverdin and independently Benkisser were the first to practise the sterilization of catgut by hot air. The catgut is heated for three hours up to 140° C. in a well regulated hot air sterilizer. In spite of the great heat the gut keeps its elasticity and firmness. Certain precautions must be taken nevertheless, or it becomes brittle and useless. At first Reverdin believed that the fat present in the gut was the cause of failure, but it is the water, rather than the fat, which is the source of the mischief. To obtain good results from this method of sterilization, it is necessary either previously to remove the water by placing it in absolute alcohol for 24 to 48 hours, or to heat the sterilizer very slowly, so that the water is vapourized before the higher degrees of temperature are reached. Only gradually and after some hours should the temperature reach 140° C. The process is difficult and complicated, and requires careful supervision, a circumstance which must stand in the way of its general

adoption. After futile experiments with oil and glycerine by Benkisser, Brunner found that by the use of xylol heat could be employed in the sterilization of catgut. Placed in xylol, it can be kept at 100° for hours, and can even be brought to 130°-140° C., the boiling point of xylol. According to experiments made by the author, there are numerous substances which can be used in a similar manner, for example, ethereal oils such as those of bergamot and cloves, and aniline oil. But it is a very singular fact that these fluids, heated to 100° C. or even up to their boiling points, accomplish very little in the way of killing bacteria, and are conspicuously inferior to boiling water in this respect. Brunner found that strong anthrax spores were not killed by boiling xylol at 140° C. in less than 1½-2 hours, nor by xylol at 100° C. in less than 2½ hours. Less resistant anthrax spores, which were destroyed in two minutes by boiling water, and in five minutes by steam, were found by the author to be alive after being in aniline oil at 100° C. for an hour. And so if we follow Brunner and use xylol in the sterilization of catgut, several hours will be necessary just as when hot air is used. Brunner places the catgut in a closed vessel containing xylol, which is put into a steam sterilizer. The catgut is then washed with alcohol and kept in an alcoholic solution of sublimate.

In the royal Clinic at Berlin the old method of treating catgut with sublimate has been retained (von Bergmann) after trial of various others both in practice and by experiment. For even the method of preparation proposed by Brunner is more complicated and difficult. The catgut must be carefully freed from all water just as for the hot air process of Benkisser and Reverdin, and for the same reason. Many experiments

have been made, and have proved that threads of catgut impregnated with pus or anthrax spores may be as satisfactorily disinfected by the use of alcoholic solutions of sublimate as by that of heat. The catgut used in the Clinic was repeatedly examined and always found to be free from germs. Catgut, submitted to the alcohol and sublimate treatment, must be free from fat, and if it is not so obtained from the maker, it must be rendered so by ether, a point to which attention has been drawn by Braatz.

Von Bergmann's method of preparing catgut is carried out as follows :—

1. The glass receptacle (figs. 22 and 23) is sterilized for three-quarters of an hour in steam.

FIG. 22.—Standing cylinder for catgut.—Threads 40 cms. in length are wound upon a glass plate.

2. The threads of catgut are wound upon glass reels or plates, as the case may be.

3. If the gut contains fat, the fat is removed by allowing it to lie in ether for 24 hours.

4. After the ether has been poured off, the gut is allowed to lie in an alcoholic solution of sublimate, of the following composition :—

Sublimate	10·0
Absolute alcohol . . .	800·0
Distilled Water . . .	200·0

5. This solution is renewed after 24 hours, and again after 48 hours. This part of the process must last not less than 48 hours.

6. The gut is removed from the sublimate solution and placed in alcohol, which should be absolute if a stiff gut is required, or diluted with not more than 20 per cent. of glycerine for a softer form of gut. Sublimate may be added, as in the fourth stage of the process, if desired. The vessels must always be kept well closed. This method is easy to carry out even on a small scale.

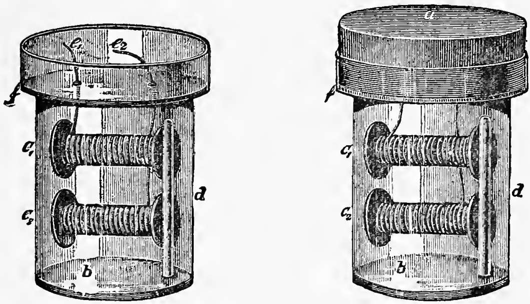

FIG. 23.—Portable vessel for catgut.—Closed with an india-rubber stopper (*a*), which can, like the glass vessel (*d*), be sterilized in steam. The catgut is wound on reels (c_1 c_2); the ends of the threads are carried through a glass plate (*f*), which is placed in the upper opening of the vessel.

It is important to know the time in which we may reckon that catgut will be absorbed in a wound, and the manner in which this is accomplished. Investigations by Flemming, Tillmanns, Lesser, Hallwachs, and others all go to show that catgut left in a wound first of all swells, and is then penetrated by leucocytes. Soon after this, the living tissues grow into it and take its place, while it is transformed into a granular detritus, which is either simply liquefied and absorbed, or carried

away by wandering cells (Tillmanns). This sequence of events is the same as that which occurs when any dead animal tissue is placed in a living organism. The length of time necessary for this to be accomplished appears to be about the same, however the catgut is prepared. On the whole too much stress has been laid upon the merits of the different processes in this respect. Lesser studied minutely the time necessary for the absorption of catgut in the bodies of rabbits, the catgut having been obtained from England and prepared by Lister's method. Up to the twenty-second day, he found hardly any change at all, and in two or three cases he discovered remains of the gut after the expiration of 85 days. In the experiments of Hallwachs, catgut, which had healed into the bodies of animals, could no longer be found after the lapse of six months. Complaints have repeatedly been made by operators, that catgut, like silk threads, has had to be removed more than four weeks after plastic operations on the vagina, for instance; and in one or two cases, catgut threads have been found during an operation, in peritoneal and uterine scars $1\frac{1}{2}$ and 2 years after their insertion. There is, therefore, no foundation for the fear, which has from time to time found expression, that catgut ligatures or sutures may be too quickly absorbed. In some cases they last longer than is desired.

CHAPTER IX.

Aseptic Drainage of Wounds.

The different devices for draining wounds—Drains that can be absorbed by the tissues—Drainage tubes of india-rubber, glass, and caoutchouc—The use of capillarity in draining wounds.

The removal of secretions from fresh and suppurating wounds may be accomplished in various ways :—

1. Simple openings may be made.
2. Tubes may be inserted.
3. Capillary action may be made use of.

It is not necessary here to describe in detail where and how the openings should be made in a wound to allow the secretions to escape, nor how they may be kept widely open. In many operations no further steps need be taken to ensure the discharge of all that should escape from the wound, when such openings have been made, or gaps have been left, in the line of suture. When more than this is required, there are many plans open to us. We may use tubes of glass, metal, india-rubber, or caoutchouc, or we may prefer bundles of horse-hair (White), glass-wool (Kümmel), silk-threads, or cotton wicks. In any case, whatever we select must be absolutely free from germs.

The idea of using, for the drainage of aseptic wounds, some material capable of being absorbed by the tissues (Neuber), was at one time in high favour, and not without good show of reason. At first when the wound is fresh and the discharge copious, the tube would be

entire; then as the surfaces of the wound begin to adhere and the discharge to diminish, the tube would begin to be absorbed, and finally would completely disappear; so that even deep wounds with a copious secretion could be made to heal without change of dressing. The drains of this nature, proposed by Neuber, which were made from the compact tissue of ox-bones by decalcification and were rather expensive, have not fulfilled what was promised of them any more than the cheaper decalcified bones of birds proposed by Trendelenberg and MacEwen, or Watson Cheyne's bundles of catgut. They cannot be relied upon; at one time, a bone tube rapidly disappears, long before it was intended to; at another time, it will last many weeks without undergoing any change. Most surgeons prefer to work with drains which are not altered by the tissues, and to have the dressings changed and the tube taken out after five to eight days.

India-rubber tubes very properly are the most used of all the tubular forms of drains, only a few operators preferring those made of gum-elastic or glass. These latter, especially those made of glass, are inconvenient because they cannot be cut to the right length as ordinary rubber tubes can, and so a large number of different lengths have to be kept in stock, in order to be sure of always having a tube of the right length. Theoretically it might appear probable that the soft rubber tubes would be compressed in the wound, and so would not conduct so well as glass or other rigid tubes, but this is not confirmed by practical experience. Rubber tubes are always sufficiently rigid for the yielding soft parts; and where the parts are capable of exerting a more unyielding pressure, drainage tubes should be avoided for fear of ulceration or necrosis. If a drainage tube

becomes displaced, it is almost always due not to its pliability but to something else. If a tube becomes blocked, it is practically always due to thick or coagulated discharges, and not to compression of the tube in the wound. It is therefore unnecessary to harden the ordinary rubber tubes in sulphuric acid as was proposed by Javaro (1888).

It is true that glass tubes are the easiest to keep aseptic; but there is no difficulty with rubber tubes on this score. Besides, it should be remembered that rubber tubes stand boiling in water or soda solution if not frequently repeated; and that five minutes boiling kills all the germs that need be considered. The tubes may be equally well sterilized in steam, in from 15 to 20 minutes. Once rendered free from germs by these means, they can be kept aseptic most easily by putting them in strong antiseptic solutions, of which five per cent. solution of carbolic acid is the best. Sublimate is not suitable because it enters into combination with the rubber and is precipitated. The carbolic acid in which the drains are kept, must of course be changed from time to time. Before placing a drainage tube in a wound, it may for safety be once more boiled in the soda solution ready at hand.

The drain is secured by means of a sterilized silk thread, with which it is either sewn to the margin of the wound, or fastened with pins, preferably safety pins. These should be boiled in soda solution and kept ready for use dry, or in absolute alcohol in sterilized vessels, and before use put again in the boiling alkali.

For the employment of capillarity it is quite unnecessary to have recourse to such fanciful things as spun glass or horse hair; gauze is always at hand ready sterilized for the dressings, and it takes up fluids ex-

cellently. A strip of gauze laid in the corner of a wound will be at least as efficacious as all the other materials proposed for the purpose, which require special and troublesome preparation.

CHAPTER X.

Aseptic Sponges.

Whatever is used in sponging wounds must be free from germs—Pads of gauze are the best form of sponge—A cheaper substitute—Sponges and the dangers in using them—Sponges are sometimes however indispensable—The use of soda in disinfecting sponges.

Surgeons who dispense with irrigation during and after an operation, must have something aseptic with which wound products, blood, pus, &c., can be sponged away from the wound; and in any case something with which the surfaces of the wound may be temporarily compressed is necessary. The material used must absorb well and rapidly, and at the same time must leave no particles or fibres upon the wounded surface. A material which satisfies all requirements, and which can be easily sterilized, is absorbent gauze. This is cut into squares 20 cms. each way, folded together and rolled into a ball. In operations in which there is much bleeding, the amount required will certainly be considerable, and since each pad can only be used once, this ideal sponging material is expensive. Small bags of moss or wood wool are a somewhat cheaper substitute for gauze. The balls of gauze or the bags are sterilized in steam for half an hour with the dressings, and are always destroyed after having been used.

Nothing, no doubt, is so convenient for this purpose as a sponge; its absorbent powers, elasticity, and softness are unsurpassable. From the point of view of

asepsis, however, the use of sponges is attended with certain drawbacks. First and foremost, without entering for the present into the difficulty of sterilizing them, is their high price. The price of really good sponges is such that they cannot very well be destroyed after being once used in an operation. As a general rule, therefore, the same sponges must be used for a whole series of surgical procedures. In fact it is usual to have only a limited number of sponges in use at an operation, and these, after they have been soaked in blood or pus, are washed out, dipped for a moment in an antiseptic, and then handed again to the surgeon. The good qualities of a sponge come out only when it is wet; it can never be used dry like pads or bags of gauze. The repeated use of the same sponges at the same or different operations considerably increases the danger of infection, and must give rise to doubts and suspicions in the mind of the surgeon who thus uses them. It is so important that whatever is used for sponging, and thus brought into immediate contact with the wound, should be entirely free from germs, that economy would be more wisely exercised in the outer dressings than in this. Whenever it is feasible the best and safest material is sterilized gauze, and the use of sponges should be as limited as possible.

Sponges, no doubt, cannot be entirely discarded. In major operations on the buccal cavity, resection of the upper jaw, uranoplastic operations, and also in laparotomy, nothing can be used in place of them for mopping out or plugging large cavities.

Some surgeons have regarded the disinfection of sponges as very easy. Kümmel was of opinion that if sponges, even after being saturated with putrid material, were washed for three or four minutes with soap

and warm water, and then put for one or two minutes in five per cent. carbolic, chlorine water, or one per cent. solution of sublimate, they no longer contained any germs capable of life. In this he was wrong as we now know.

That sponges cannot be cleansed in so simple a manner follows *à priori* from their great powers of absorption; to be convinced of this we have only to consider how steadily they suck up pus, blood, or any infected fluid. This has always been felt by practitioners, and few have been satisfied with so simple a process of sterilization. Placing them for a long time, even for a week, in strong antiseptic solutions is at least held necessary. The system of fixed days has in one form or another often been adopted, and is well known. On visiting hospitals where sponges are commonly used, we still often see large jars for sponges with the name of a day of the week in large letters upon each of them. This is an excellent device. There are sponges for each day of the week, and they are never used on any other. After having been used, the sponges are thoroughly washed out, and are then placed in five per cent. carbolic or 1 in 1000 solution of sublimate. There they are left to soak till the day comes round, the name of which is upon the jar in which they lie. By placing them for eight days in a strong germicidal solution, much more can be done than in a few minutes, and in many cases this method of disinfection may suffice. But it is not absolutely reliable; we know, for example, that anthrax spores may be still alive after fourteen days in five per cent. carbolic acid, and that the ordinary actively growing forms, cocci and bacilli, when they are enveloped in fat do not lose their vitality after eight days in sublimate.

Permanganate of potassium is often used to disinfect sponges. The sponges are first of all thoroughly washed, they are then put into a solution of permanganate of potassium 1 : 500, and are afterwards bleached in a 10 per cent. solution of hyposulphite of sodium to which is added eight per cent. of pure hydrochloric acid. Then they are again rinsed in water, and finally kept in five per cent. carbolic acid. It is not to be wondered at that this complicated process is not entirely to be depended upon, and that Frisch, when investigating the matter in Billroth's Clinic, found germs in twenty per cent. of the sponges so prepared; for these measures are not more effectual than the use of carbolic acid and sublimate.

There would be no difficulty if sponges could be sterilized in the usual way by means of heat. But sponges will not stand either boiling in water or steaming; they shrivel up and become quite hard. Dry heat alone can be used for this purpose. Benkisser was the first to make use of such a process. He put the sponges in a hot air sterilizer and heated them for several hours at a temperature of from 140°-150° C. Sponges stand this well but only when no trace of moisture is left in them, as otherwise the heat makes them shrivel up and become quite hard. Sponges must therefore be absolutely dry before disinfection, and must then be brought up to the high temperature only very slowly, so that before 100° C. is reached, even atmospheric water escapes from them. The necessity of the sponges being absolutely dry before they are sterilized considerably detracts from the value of this process otherwise so satisfactory, and makes it impracticable for ordinary surgical practice.

The process, next to be described (Schimmelbusch),

is simple, and in point of security better than those given above. The sponges are first of all freed from the coarser forms of impurity: this is necessary in almost all cases. If they have never been used the sand and shells that they contain must be removed by beating them. After that they are soaked for a long time in cold water, and from time to time squeezed out. Sponges, which have been used, are cleansed as far as possible by energetic washing, first in cold and then in warm water. They are then well squeezed out, done up in a linen cloth, or best of all put into a special bag. A large vessel of boiling soda solution (one per cent. of soda) is then prepared, and the bag containing the sponges is placed in the hot alkali, so as to be entirely submerged; as we have already said, sponges shrivel up if they are boiled, so the soda solution must be taken off the fire shortly before the sponges are put into it. After lying for half an hour in the hot alkali the sponges can be taken out, and are free from pathogenic organisms; they are squeezed without being taken out of the bag, and the soda they contain is washed out by wringing them out in boiled water; they are then to be kept in an antiseptic solution. Sublimate solution (1 in 2000) is the best for this purpose; carbolic acid, which turns the sponges a very bad colour, is less to be recommended. But sponges bleached in sulphurous acid are blackened by sublimate, and must therefore be avoided.

Sponges which have been saturated with resistant anthrax spores and pus, are found to be completely sterilized by the hot soda solution in ten minutes, so that the half hour allowed is fully sufficient. The explanation of this depends upon the fact that soda solution maintains a temperature of 80°-90° C. for a long time after removal from the burner, and soda solution

at this temperature is sufficient to kill anthrax spores in a short time (Behring).

After being submitted to this treatment a considerable number of times, sponges gradually lose their elasticity; but this does not take place till they have done duty long enough for them to be destroyed and replaced by others.

There are two objections to the use of sponges in aseptic surgery, which have not been disposed of. In the first place they must be used wet, and must, therefore, be dipped in some sterilized fluid; and secondly they always retain traces of the antiseptic in which they have been kept.

CHAPTER XI.

The Aseptic Use of Hypodermic and Aspirating Needles.

Cases of infection after hypodermic injections—Many of the fluids most often employed for injection are very rich in germs—Prevention of the development of bacteria in these fluids—Disinfection of syringes—Boiling—Construction of syringes—Disinfection of needles.

Subcutaneous injections and injections into diseased organs, and also the aspiration of cavities containing pus or other fluids, are at the present time so widely made use of both for diagnostic and therapeutic purposes, that it is necessary to discuss somewhat in detail the means by which they may be carried out aseptically.

No one thinks of injecting a joint or of aspirating an effusion of blood without the most scrupulous aseptic precautions; but an ordinary hypodermic injection is quite another affair, and antiseptic measures are with impunity neglected in such a number of these injections every day, that it may seem quite unnecessary to lay any stress upon them. That infection is so seldom set up in this way is largely due to the fact that the subcutaneous tissue, into which the injection is made, is comparatively little prone to infection by the needle, but is partly also due to the rapidity with which absorption takes place in it, the germs which are introduced being distributed before they can establish themselves and multiply. If the substances injected are not

readily absorbed, or by damaging the tissues increase the risk of infection, the conditions are altered. It is not uncommon, for instance, for abscesses to be formed after injections of calomel, oleum cinereum, &c. And similarly infection is more likely to follow when the patient is not strong, and predisposed to it by cachexia or some other cause. The presence of numerous abscesses in the body may be one point in favour of the diagnosis in certain cases of severe morphiomania, and multiple subcutaneous centres of suppuration are often found post-mortem in people, who have perished from painful cancerous maladies, and are a sure sign that morphia has been frequently injected to relieve the patient's sufferings.

Fatal cases of infection by hypodermic injections are also recorded. The following case is mentioned by Bouchard: an attendant in his service, a victim to the morphia habit, suddenly fell ill with severe erysipelas; upon enquiry the cause was found in an injection, which the patient had given himself with a dirty Pravaz syringe. In the evening the house physician gave this attendant, suffering from erysipelas, a morphia injection with an ordinary syringe; he only superficially cleaned the syringe, and used it before finishing his round to inject four patients suffering from tabes. Two days later all four fell ill with severe erysipelas, which started from the punctures, and caused the death of three of them. In the year 1882, two typhus patients in the Charitékrankenhaus, in Berlin, were treated with injections of tincture of musk for symptoms of collapse, as communicated by Brieger and Ehrlich. The same solution and the same syringe were used, and both of them developed severe purulent œdema, starting from the puncture, to which both quickly succumbed. Two

cases of fatal phlegmonous erysipelas after subcutaneous injections of quinine, have been communicated by the Russian military surgeon Herschelmann. It was observed in the dermatological Clinic at Breslau, that anthrax was conveyed by subcutaneous injections. Four patients were attacked, more or less severely, with anthrax œdema, which developed from the spot where arsenic had been injected. The solution of arsenic was free from germs, and Jacobi, who made careful bacteriological examination of these cases, supposes that the first patient injected, who was employed in a laundry, was already infected at the time of the injection, and that those subsequently injected were infected from him by the syringe. Two cases are on record in which even tuberculosis was inoculated by subcutaneous injections. One case was reported by König, the other described by von Eiselsberg.

The source of infection in these cases may be any one of the following:—

1. The skin of the patient.
2. The injection fluid.
3. The syringe.

The danger of conveying germs from the skin on the point of the needle is certainly not great, if the skin be moderately clean. For ordinary hypodermic injections measures for the disinfection of the skin need hardly be taken. When one of the larger joints is to be aspirated (or injected), this must be done according to the directions already given (Chapter V.). Too little importance is generally attached to the sterilization of injection fluids. Many of the fluids used are sent out by the apothecary with bacteria in them, and become only richer in them when in use. Minute investigations upon this point have been carried out in von Bergmann's

Clinic by the author and Hohl, and the number of germs contained in injection fluids received from various Berlin druggists, and in those in use in the Clinic, has been determined. According to these investigations one c.c. of the one per cent. solution of the hydrochlorate of pilocarpine contains countless organisms; the ordinary solution of ergotin contains about 10,000 in one c.c., and the one per cent. solutions of atropine, hydrochlorate of morphia, and hydrochlorate of cocain, are also rich in germs. The one per cent. solution of morphine, used in the wards of the royal surgical clinic, which is kept in bottles with glass stoppers, and is freshly prepared once in every six or eight weeks, showed in repeated examination from 200 to 300 fission fungi in each c.c. Iodoform in glycerine (ten per cent.), camphor oil (ten per cent.), hydrochlorate of apomorphia (one per cent.), bisulphate of quinine (ten per cent.), antipyrin (fifty per cent.), combinations of mercury, as well as the stronger solutions of some of the substances mentioned before, for instance the ten per cent. cocain solution, were found, as far as could be ascertained, to be free or all but free from germs.

It is very important to know accurately how far fission fungi, which get into injection fluids, are able to retain their vitality or to increase in them, for clearly the danger is very great if, for instance, pyogenic cocci, or the cocci of erysipelas, can develop and multiply freely in these solutions. Investigations upon this point have been instituted by Ferrari, and we have ourselves also given some attention to it. Small quantities of pyogenic cocci were conveyed into previously sterilized solutions, and then by means of plate cultivations, according to Koch's plan, it was determined whether the fungi were killed or had multiplied. Ferrari arrived at

the following conclusions: the microbes of ordinary pus (staphylococcus pyogenes aureus) were immediately killed in ether, tinctura moschi, and in saturated solutions of quinine. In ten per cent. cocain solution they were still alive after one hour. In two per cent. morphia solution they were not killed till after twenty-four hours. In glycerine the staphylococci live for six days, but their number gradually diminished all the time. On the other hand, in distilled water, in one per cent. atropine solution, as well as in the half and one per cent. morphia solutions organisms not only remained alive for weeks, but soon multiplied enormously. Our investigations, which supplement those of Ferrari, gave very similar results; 10 and 20 per cent. solutions of sulphate of quinine killed staphylococci very soon, 50 per cent. antipyrin and 20 per cent. benzoate of caffeine acted similarly. In nitrate of strychnine (one half per cent.) germs were preserved for more than eight days; in one per cent. hydrochlorate of cocaine thousands were still present after eight days; in one per cent. atropine and one per cent. morphia solution their numbers increased. These laboratory experiments confirm the results that we obtained from examination of solutions in use in the clinic; the solutions, that is, which were proved to allow germs to live and multiply, were the same as those therapeutic preparations which we found to be most rich in germs. The solutions which require the greatest caution are some that are most frequently used in this way. Any of the following may contain large numbers of germs:—

One per cent. solution of sulphate of atropine.
One per cent. solution of hydrochlorate of morphia.
One per cent. solution of cocaine.
One per cent. solution of pilocarpine.
Ergotin solution.

The importance of this subject is most likely to be recognised in the case of the solution of cocaine, so much used in minor surgery. For in operating on a sebaceous cyst the most careful aseptic precautions must be stultified, if in producing anæsthesia we inject under the skin some thousands of suppurative germs. Clearly it is imperative that injection fluids be sterile.

In the case of fluids with distinct germicidal properties, and of those which do not allow bacteria to multiply in them, there is little difficulty in attaining this. Special measures are quite unnecessary in the case of germicides such as ether, alcohol, concentrated iodine solution, sublimate solution, stronger carbolic solutions. Certain other substances such as iodoform glycerine, or iodoform oil, provided that contamination is not permitted, are safe for a long time after a single sterilization because they are most unfavourable media for bacterial growth. Iodoform emulsion is most satisfactorily sterilized by placing the bottles containing it, with their stoppers out, in steam for an hour; the process need be repeated only in special cases. Iodoform in glycerine or oil takes no harm from a temperature of 100° C., at least we have never seen any symptoms of iodine poisoning after injections with glycerine emulsion so treated. According to von Stubenrauch it is important that the vessels in which the emulsion is contained should be open during the sterilization. In closed vessels iodine is said to be liberated at 100° C.

If a steam sterilizer is not available, the oil may be boiled, the bottle sterilized in boiling water, and cleansed with sublimate solution and ether, and then the emulsion made with iodoform powder in the sterilized bottle. In this way no steps are taken for the sterilization of the iodoform, and since it may harbour

bacteria, the procedure is not absolutely faultless. It is better therefore, as Böhm suggests, to first wash the iodoform with a solution of sublimate in water. We object to von Stubenrauch's plan of using a solution of gum in the emulsion of iodoform (·5 per cent. solution of gum, 180 parts; alcoholic solution of iodoform, 20 parts), because a solution which contains organic substances is a good medium for bacterial growth, and is always more difficult to sterilize or to keep sterile, than a glycerine mixture.

According to Böhm as much as 5 per cent. of iodoform will dissolve in sweet oil of almonds, and forms an amber coloured fluid very suitable for injection. We are able to confirm this, and have only retained the glycerine emulsion for our own use, because we have no fault to find with it on any ground.

Greater difficulties arise in the case of those injection fluids mentioned above, in which the growth of bacteria is favoured, or which form more or less good media for them. A sure means of avoiding infection in using them would be to boil them before every injection, but this would be too complicated, and would after frequent repetition alter their chemical composition. These solutions must of course be kept in properly stoppered bottles, the quantity kept in stock must not be too large, and their aseptic character must be preserved by the addition of substances which inhibit the growth of micro-organisms. Camphor has been recommended for this, but the recommendation is not we think justified by bacteriological investigations. Camphor is only very slightly soluble in water, and its inhibitory action on the growth of micro-organisms is quite inadequate. But small quantities of creasote, carbolic acid, and sublimate have been widely used. We find that carbolic

acid, which is much used for this purpose, answers best, and we should regard the usual proportion of two or three drops of liquefied carbolic acid to 30 c.c. of injection fluid as sufficient. So small an amount of carbolic acid cannot possibly do any harm.

Syringes are very difficult to keep clean, the piston in the ordinary forms being particularly difficult to sterilize. R. Koch, in the syringes designed by him, which have lately become so widely known, has circumvented this difficulty in an ingenious manner. He entirely does away with the piston and uses an india-rubber ball to drive out the contents of the syringe after it has been filled. The syringe (fig. 24) consists of a graduated glass cylinder at one end of which is the

FIG. 24.—Hypodermic syringe devised by R. Koch.

needle, at the other the india-rubber ball. Although this syringe as an aseptic instrument is perfect, it is nevertheless a fact, that the majority of practitioners do not take to it. It is not convenient for the aspiration of fluids nor for the injection of thick oily substances, and this, it cannot be denied, is a bar to its adoption for ordinary practice. Syringes constructed upon similar principles, as for example Strohschein's, are open to like objections.

We are not at all sure that it is possible to do without piston-syringes in practice, and of late years they have been considerably improved. We have made comparative estimates of the value of different methods of disinfecting syringes. Some form of piston-syringe was chosen, such as that devised by Overlach, which can

be completely sterilized in boiling water, and after sterilizing, it was infected with bacteria (Staphylococcus pyogenes and Bacillus pyocyaneus) by sucking up broth cultures or pus, and attempts were then made to sterilize it in various ways. Simply pumping up sterilized water and syringing through it several times, was shown in these experiments to be of very little value. The number of germs in the syringe certainly became smaller, but after filling and emptying it ten times there were still thousands always present. We tried also three per cent. carbolic acid, 1 in 2000 sublimate, absolute alcohol, and boiling water. Boiling water gave the best results as might be expected, the syringe was sterile after it had been filled and emptied once. Next to boiling water absolute alcohol had most effect on the

FIG. 25.—Overlach's hypodermic syringe.

organisms and three per cent. carbolic least. After syringing through three per cent. carbolic ten times, we still got over 5000 germs.

These experiments show that we must try to construct piston syringes so that they can be boiled, for this is clearly the best way to disinfect them; gum elastic and leather pistons must be avoided; the syringes must be made of metal and glass, and the pistons of some substance which will stand a temperature of 100 C. well. The syringes of Overlach, Meyer and Roux fulfil these requirements when made of the size suitable for hypodermic injection.

Overlach's syringe (fig. 25) consists of a glass cylinder, the mouth piece and piston of which are formed by a vulcanized india-rubber ring and a screw arrangement.

It is not in the least injured even by frequent boiling. In Meyer's (fig. 26) and Roux' syringes the mouth-piece is drawn out of the glass cylinder. In Overlach's as well as Meyer's syringe the piston is made of asbestos; in Roux' of elder pith. In the two former use has been made of Hansmann's invention for regulating pistons. By screwing together two metal discs on the piston rod, the piston, consisting of asbestos, is pressed together, and made to bulge out between the discs, so as to fit the cylinder more closely.

Asbestos pistons are objectionable being apt to crumble after frequent use, and so not only do not fit so well but also allow particles of asbestos to get into the injection fluid. This is especially the case

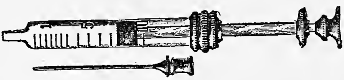

Fig. 26.—Meyer's hypodermic syringe.

with larger syringes holding from 40 to 100 grammes, and up to the present time it has not been found possible to make such syringes with asbestos pistons. The instrument-maker Baumgartel, of Halle a.S., has overcome this difficulty by the ingenious use of linoleum, and has constructed syringes of all sizes which can be completely boiled. These syringes like Hansmann's have an asbestos piston which can be regulated, that is, it can be compressed by screwing together its plates, this, however, carries a linoleum plate on both surfaces turned towards the lumen. The glass cylinder is set in metal, which is made watertight above and below by linoleum instead of the usual leather washers. The syringes have been approved of in what was formerly

von Volkmann's clinic and is now von Bramann's; we have ourselves also found them satisfactory.

Syringes made of more than one material, for instance glass and metal, have this disadvantage, that when boiled the glass often cracks because the different substances expand unequally. This is also a defect of Baumgartel's syringe, it must be warmed and cooled with the greatest care or else the glass cylinder will crack.

The instrument-maker Schmidt of Berlin has lately constructed a syringe entirely of metal (fig. 27). From personal experience we find that this syringe fulfils all

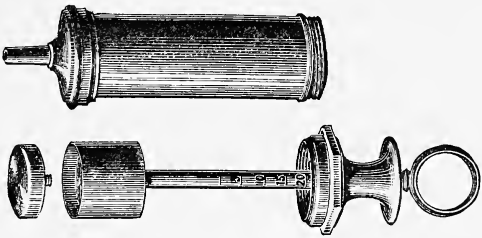

FIG. 27.

requirements of an aseptic instrument with the single exception that it is not transparent. The cylinder is of nickel and made in one piece; the piston consists of a thin, hollow, elastic spring cylinder of nickel which fits closely into the barrel of the syringe. The metal surfaces are made to slide on one another more easily by lubricating them with Sarg's glycerine, which may be boiled (not with oil). The syringe is always ready for use and is not damaged by frequent boiling.

We will not go too much into detail, but as the subject is one with which the practitioner must be familiar, we will just mention certain other forms of syringe

which have not at present been made large enough to hold more than one or two c.c. Thus, for example, syringes have been designed which retain the leather piston, but are so constructed that the fluid does not come into contact with either the piston or the cylinder (Beck, Liman and others). But it is difficult to prevent some of the fluid getting out of the receptacle into the cylinder, and *vice versa*. Reinhardt has described a syringe in which a new piston of cork is screwed on to the piston rod for every injection. Farcas attempted to make the piston water-tight by introducing an elastic ring.

The needles should be disinfected by boiling them in water, or better still in soda solution, and should therefore be made entirely of metal. Heating the needles to redness in a naked flame is only possible when they are made of platino-iridium. Steel needles if heated to redness are so softened as to be at once rendered useless.

CHAPTER XII.

Aseptic Principles applied to the Passage of Catheters and Bougies.

The cause of decomposition of urine in the bladder—Healthy urine in a healthy bladder is free from germs—In decomposed urine bacteria are always found—The way in which infection takes place—Disinfection of instruments—Metal instruments—India-rubber instruments—Catheters and bougies with a covering of varnish—The micro-organisms in the urethra—Disinfection of the urethra.

Although as early as 1860 Pasteur had recognized that the decomposition of evacuated urine in the air, and that of the urine in the bladder in cystitis depended upon the action of bacteria, our knowledge upon the subject of these processes is still far from complete. Indeed Pasteur's work on the subject led to views which had a certain appearance of finality that is lacking about the results of more recent work. One organism, "une torulacée en chapelets de très petits grains," was supposed to bring about the peculiar ammoniacal decomposition of urine both in the bladder and after it had been voided. Later and more detailed investigations tend to show that we have to deal with more than one micro-organism. Rovsing after accurate bacteriological investigations ascribes the causation of severe cystitis in the majority of cases to staphylococci and streptococci which he has shown to be identical with the well known pyogenic forms. According to the investigations of Schnitzler, thirteen out of twenty cases of

purulent cystitis were to be referred to a bacillus, which the investigator designates urobacillus pyogenes septicus.

According to the more recent investigations of Krogius, the bacterium coli commune and the proteus vulgaris (Hauser) play a chief part in the ætiology of cystitis. In any case it is not the organisms which cause ammoniacal decomposition of evacuated urine, and which usually go by the comprehensive name of micrococcus ureæ, that are also responsible for the production of cystitis. The former are often derived from the air and, some of them at any rate, cannot grow without access of air: whilst according to the investigations of the physiologists, Planer and Pflüger, no free oxygen is present in the bladder, and only the so-called anaerobic organisms can grow there.

Nevertheless two points remain settled; in the first place, urine in a healthy bladder is always free from bacteria; and secondly, when decomposition takes place in the urine, within the bladder, bacteria are always found.

Numerous investigators have proved the absence of germs from the bladder in health (Pasteur, Lister, &c.), and we will only mention here the ingenious experiments of Cazeneuve and Livon. These experimenters produced retention of urine in dogs by ligaturing the prepuce, and then cut out the distended bladder after ligaturing the ureters and urethra; they were able to keep it for a long time at the temperature of the room and in an incubator without decomposition or putrefaction occurring in the urine, which certainly would have occurred under the circumstances if there had been any micro-organisms in the bladder.

We need not here discuss in detail the route by

which microbes arrive in the bladder, whose action is to set up decomposition of urine with such disastrous results to the patient, nor need we enter into the question of the relative probabilities of their coming down from the kidneys or up by the urethra. Clinical experience teaches us that it is very common for the introduction of instruments into the bladder through the urethra, catheters and bougies especially, to be followed by severe symptoms of infection by organisms; and this is sufficient to make us demand the most careful aseptic precautions in these manipulations.

Cystitis following catheterism is by no means a rare form of disease, and every practitioner can recall cases in which he has seen severe cystitis develop after a dirty instrument has been passed frequently or it may be only once.

Experiments have frequently shown that in animals infection of the bladder is not brought about by the introduction of pathogenic germs, if the urino-genital tract is completely healthy; that the free flow of urine is quite sufficient to wash out the infective germs that have been introduced, and that some pathological factor or other, such as retention or injury, is necessary for the development of cystitis. Nevertheless the results are not uniform. Schnitzler succeeded in producing in perfectly healthy animals a severe infection of the bladder by simply introducing pure cultivations of his uro-bacillus pyogenes septicus.

But this question has but little practical importance because healthy bladders are very seldom exposed to instrumentation, and as a rule some pathological condition is present involving liability to infection.

The instruments which we have to introduce into the bladder are made either of:—

1. Metal, or
2. India-rubber, or
3. Silk or cotton covered with varnish.

However it may be proposed to disinfect these instruments, it should be borne in mind that before they are used they are always greased or oiled to make them pass smoothly and easily through the urethra, and that this greasiness, as we have frequently pointed out before, offers a special protection for the harbouring of micro-organisms. To merely dip them therefore into some weak solution, as is often done, is never sufficient disinfection: sterilization must be energetically carried out.

Metal instruments, catheters, or bougies, are very easy to disinfect by simply boiling them just before they are used (*vide* Chap. VI.). They can easily be kept aseptic, without being spoilt, in carbolic, glycerine, or alcohol. The chief thing to be observed is to have them thoroughly washed and scoured inside and out each time they are used.

The india-rubber instruments, what are known as red or Nélaton's catheters, are more difficult to cleanse. Occasionally, at any rate, they may be disinfected in steam, boiling soda solution, or boiling water. For long-continued or daily use they must constantly be kept in strong carbolic, or a frequently renewed solution of sublimate; but before being used they must be freed from any of the antiseptic that may cling to them, by wiping with a piece of sterile gauze or by washing in sterile water; because the urethra is very sensitive to these antiseptics.

The common varnished instruments are difficult to disinfect. Boiling and steaming they will not stand, much less heating in dry air. Even remaining a long

time in antiseptic solutions, such as carbolic and sublimate, renders them useless. Albarran has for this reason had instruments made which are covered with caoutchouc, and can be boiled or kept for a long time in sublimate without being spoilt. These caoutchouc catheters have not as yet been adopted by other surgeons.

It is important that it should be known that a smooth bougie or catheter can be made externally almost free from germs by mechanical means, rubbing it with a piece of sterilized gauze and warm water or sublimate solution. The author has made actual experiments with the common red varnished bougies, first infecting them with pure cultivations of different bacteria and then rubbing them off thoroughly. After rubbing them for a minute with a wet piece of gauze and subsequently with a dry piece, they were almost always free from germs.

In order to clean a catheter inside, warm water, warm sublimate solution, or carbolic lotion must be energetically syringed through it. Farcas has described a small steam apparatus, a small steam kettle to the spout of which a catheter can be fastened. The water in the kettle is boiled by means of a spirit lamp, and the steam is forced out through the spout and into the catheter. This apparatus at any rate is more energetic than any syringing.

The route by which catheters and bougies must reach the bladder is inevitably one that is richly stocked with bacteria. The investigations of Lustgarten and Mannaberg as well as those of Rovsing agree in showing that the healthy urethra is always inhabited by numerous organisms, and by some at least which can cause urine to decompose. That this unfortunately is the case is

proved when a catheter has to be left in the urethra several days. The normal occupants of the urethra are then so multiplied as to produce inevitably, and almost without exception, urethritis and catarrh of the bladder. But the mere passage of catheters even when repeated frequently does not seem to involve any considerable risk of infection by these organisms; the strongest proof of this fact is the clinical experience that a catheter, provided it is clean, may be passed without producing cystitis or other trouble. But the condition of the urethra must of course be taken into consideration before instruments are passed into the bladder; a catarrhal or purulent inflammation of the urethra is an absolute contra-indication for the introduction of any instrument into the bladder through the urethra. When in such cases urine must be withdrawn, preference should undoubtedly be given to puncture of the bladder.

In any case before either a catheter or a bougie is passed, the orifice of the urethra must always be cleansed, and where special care is desirable it would be well to irrigate out the urethra with sterilized water, salt solution, or boracic acid.

CHAPTER XIII.

The Sterilization of Fluids for Washing and Irrigation.

The ground water is free from germs, but that on the surface of the earth always contains germs—The number of germs varies within wide limits—Pathogenic germs in water—Sterilization of water for surgical purposes—Methods of sterilizing water—Precipitation—Filtration—Boiling—Addition of antiseptics.

The ground water in the interior of the earth is always free from germs according to the investigations of Carl Fränkel: the water which rises as vapour from the surface of the earth, and is then condensed into clouds in the colder regions above, must also be free from germs; for no bacteria are given off from moist surfaces, as we pointed out in Chap. II., and therefore none can rise into the air with water vapour. But when the ground water comes to the surface, or the atmospheric water descends as snow or rain, it is usually very rich in germs; for it has passed through regions in which germs abound, in one case the lower strata of the atmosphere, in the other the surface soil of the earth, and has taken up organisms in greater or less quantities. Rain-water contains germs even as it falls, for dust composed largely of bacteria is caught up and carried down by the falling drops; spring water is infected as it passes through the superficial layers of the earth, where organisms abound, or through a pipe which is hard to keep clean. It is easy to see that water may contain thousands of germs, if it stands

upon or percolates through a soil full of bacteria upon which refuse and decomposing organic matter of all kinds is deposited. The number of bacteria present in water varies within wide limits, from the few fission fungi in 1 c.c. of good spring water, to the millions of microbes which are found in 1 c.c. of foul water from a river, drain or canal. In densely populated districts the rivers and streams are all contaminated to a high degree by bacterial life, and the colour, smell, and consistence of many of them would justify us in calling them rivers of putrid fluid rather than of water.

It has long been generally assumed that foul water like this was accountable for many diseases, and we have already learnt enough about intestinal mycoses, cholera, enterica and several others, to see that water is a large factor in their etiology. The germs found in water belong mainly to species which do not infect wounds, but the most virulent germs by which wounds can be infected have repeatedly been found in water. We should remember that one of the severest septicæmias to which any animals are liable, rabbit septicæmia as it is called, described by Robert Koch and Gaffky, is due to a bacillus which is derived from the water of the Panke at Berlin. Rintaro Mori isolated three sorts of pathogenic bacteria from the water of a canal. According to the investigations of Lortet and Despeignes, the water of the Rhone at Lyons always contains pathogenic germs, although this river on the whole contains only a small number of organisms. These investigators filtered the water, and injected the residue collected off the filter beneath the skin of guinea-pigs; severe pyæmia or septicæmia to which the animals soon succumbed, was observed by them to follow in every instance. The discovery of pyogenic

staphylococci in river and spring water has repeatedly been announced; but it is so difficult to identify these species that such announcements should only be taken for what they are worth. The bacillus pyocyaneus, which is the cause of blue pus, was frequently found by Tils in tap-water at Freiburg.

It is not only because water readily dissolves and carries away organic matter and the germs contained in it, and because bacteria thus liberated may be kept for some time suspended in it, that water is apt to contain large numbers of organisms; it is a substance very well adapted to the maintenance of bacterial life. Most bacteria can live for weeks and months in water, and for many kinds it contains all that is required for their multiplication. It was observed by those engaged in the examination of water in public health laboratories, that the number of bacteria in a given quantity of water was considerably increased in a short time by their spontaneous proliferation. To determine the number of bacteria in a sample of water it was necessary to examine it as soon as possible. Cramer found, for example, that the proportion of germs in tap-water at Zürich was multiplied seven-hundred-fold after standing some days, and Leone proved that fresh tap-water at Munich which contains only five bacteria per cubic centimetre after standing five days contained 500,000 germs per c.c. Even distilled water supports life in the case of certain saprophytic germs and allows the formation of a luxuriant growth. According to Wolffhügel and Riedel sterilized river water mixed with distilled water is a favourable nutrient medium for anthrax bacilli; and according to Giaxa the same may be said of sea-water for staphylococcus pyogenes as well as anthrax, a point of special interest to us. In any case patho-

genic bacteria and especially those which cause wound infection retain their power of vitality and infection for a very long time in water. Strauss and Dubarry inoculated with pathogenic organisms sterilized distilled water and sterilized water from rivers and canals. They found that all germs retained their vitality for a long time in natural as well as in distilled water. The following is an abstract from the table of their results:—

Pyogenic streptococci	lived for	15	days.
Pyogenic staphylococci	,,	21	,,
Glanders bacilli	,,	57	,,
Tubercle bacilli	,,	115	,,

Uffelmann found that in Rostock tap-water anthrax bacilli lived for two months.

Nothing in fact prevents the existence of many varieties of bacteria in water, except the struggle for existence which takes place between the different kinds. In this struggle it is the germs of disease which give way to the stronger saprophytes; so that it is generally found that they die sooner in water teeming with bacteria than in sterilized water.

The conclusions to be drawn from all this are that in water microbes are tolerably abundant, that it may harbour pathogenic bacteria, and those which cause the infection of wounds, and that it should never be poured over fresh wounds without steps being first taken to purify it of the pathogenic germs which may be present in it.

It is necessary to lay great stress upon this last point, because the habit of washing out wounds with the first water that comes to hand is one of the most widespread of all errors in the treatment of fresh injuries.

There was a time when hygienic authorities could not agree upon the question whether towns ought to be

provided with a double water supply, one of water purified with more than ordinary care for drinking and cooking, and one of water for ordinary use in washing and house cleaning. At the present day the majority are of opinion that such a distinction, with a double supply, is not to be recommended; there are practical difficulties in maintaining the distinction between drinking water and water for washing, and most hygienists require that the same water as pure as possible be supplied for all domestic requirements. In surgery, however, the principle of a double supply must be adopted, for while the water which comes into direct contact with the wound or the surgeon's hands must be absolutely free from pathogenic germs, it is a practical impossibility that sterilized water should be used for all purposes. It would be absurd to require it for cleaning the operating theatre for instance, or for cleaning the operating table and other furniture; for purposes such as this of course the ordinary water supplied to houses is good enough. The water used for the following purposes, however, must be absolutely free from at any rate pathogenic organisms:—

1. For irrigating and washing out wounds.

2. For irrigating the patient's skin, and rinsing the surgeon's hands during and before the operation.

3. For the preliminary washing of the skin with soap.

There are various ways in which it has been proposed that water should be sterilized.

1. Precipitation.

2. Filtration.

3. The addition of antiseptics.

4. Heat.

In water at rest bacteria tend to settle to the bottom, as Cramer showed, so that in the upper layers of a

mass of water which has been at rest for a long time, fewer germs are always found than in the lowest. The deposition of germs is promoted by the addition of precipitants, that is of finely powdered insoluble substances which as they sink through the water carry down the bacteria with them; any of the following for instance, sand, wood charcoal, coke, Kieselguhr, brick-dust, clay, calcium carbonate, &c. According to the investigations of Krüger the effect of these precipitants varies with the time during which the process lasts up to a certain limit, and with the amount of the precipitant used.

This plan is sufficient no doubt to give us a purer and clearer water, but it cannot sterilize it. Generally the number of bacteria is not very greatly diminished by it, and so it is quite inadequate for surgical purposes.

We may go to nature to see the action of filtration. The freedom of the ground water from all organisms, which is the result of filtering through the soil, shows that by filtration it is quite possible to render water sterile. In our imitations of nature, however, we have not attained the technical perfection of the natural process. Much is effected by the great filter-beds of sand and gravel which are in use in many places for purifying the water supply of cities, but the water they provide is never quite free from germs. The Berlin water-works at Stralau and Tegel remove the greater number of the organisms contained in the water of the Spree, amounting to several thousands, and at Stralau to several hundred thousands per c.c.; but still this filtrate is always found to contain on an average from 50 to 70 per c.c. Fränkel and Piefke proved that sand filters never offer an absolute safeguard against the passage of pathogenic germs artificially mixed with the water: a number of such germs always passes through them easily.

Besides, even if at head-quarters the water is rendered quite free from germs, it does not follow that it will be equally free when it reaches the place of consumption. The filtered water must pass through numerous systems of tubes, and so may have several opportunities of taking up pathogenic germs. That this is possible is proved by a comparison of Berlin tap water with the filtered water at the water-works: the water delivered in the houses is always found to contain many more germs, than that which has just passed through the filter at the water-works.

Water filters to provide water absolutely free from germs for immediate use on a small scale have long been sought after, but have not yet been invented. A litre or two may be furnished in a bacteriological laboratory by filtration through very thick porous cells: in this way Chamberland's clay filters are very useful. But when it is necessary to procure large quantities of absolutely sterile water in a short time these filters do not answer for long. The "Filtres sans pression" for instance (Chamberland-Pasteur), in which the water is drawn through clay cells by the syphon action of a dependent rubber-tube, very soon begin to work badly. The quantity of water which they allow to pass rapidly diminishes; and while for days the water yielded is really free from bacteria, it contains more and more every day after this date. Probably in the first instance the pores of the filter are blocked, and then finally bacteria are washed through. Filters have lately been made of Kieselguhr (a silicious marl) by Nordmeyer and Berkefeld, which are spoken very highly of by Bitter. Their practical value has recently been greatly enhanced, according to specialists, by an ingenious arrangement for cleaning them, two brushes which can be carried

outside the Kieselguhr cylinder. Like the "filtres sans pression" they cannot be depended on for long; so that water of the degree of purity required in surgery cannot as yet be obtained by filtration. Besides all filtering apparatus are too complicated for use in private practice and could be adopted only for the more extensive practice of public institutions.

The only methods of preparing sterile fluids for washing and irrigation which are at all practicable in surgery are disinfection by heat and chemical agents. The former can be carried out by exposing water in closed bottles to the action of steam; but this is not convenient because it takes too long and because even small quantities of water, 2 or 3 litres, are very slowly heated by steam. The simplest plan is to boil the water.

We saw in Chapter IV. that boiling water is the most powerful of our disinfectants and that boiling for two minutes destroys with certainty anthrax spores of great resistance. If water is boiled for five minutes, it is sterilized sufficiently for surgical purposes. The germs which survive are not pathogenic and need not be taken into account; nothing but a few spores of exceptionally resistant fungi such as the hay bacillus would be left alive and these do not signify.

Sterilization of water, as propose by Tripier, in steam under pressure at 120°, we therefore regard as unnecessary, no less than boiling for an hour so as to kill off all germs. Besides, the number of germs which survive a short boiling at 100° C. is very small. According to Miguel's investigations out of 1000 germs in water, 995 were killed by boiling a short time. The water of the Rhone contains 33,000 germs per litre according to Dor and Vinay, of these, all but 941, that is more than 96 per cent., were destroyed by boiling.

It is always so easy to obtain boiling water, even on an emergency, and the sterilization effected by the heat is so secure that it is very desirable that boiled or boiling water should be widely used in surgery. Before undertaking any operation every surgeon should regard

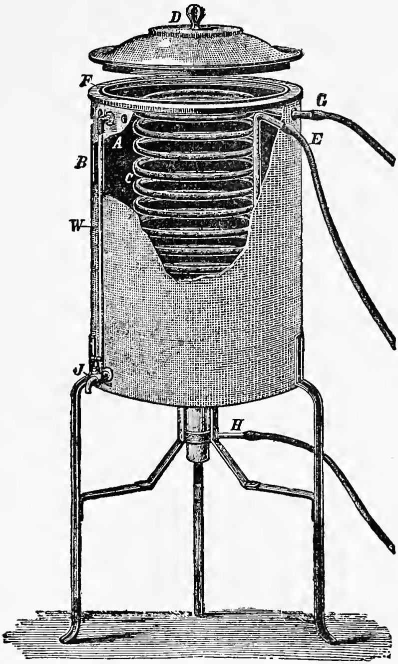

FIG. 28.—Apparatus for the sterilization of water designed by Fritsch.

a sufficient supply of hot water as of the first importance. Since water is a favourable nutrient medium for bacteria, it is best to boil the water immediately before each occasion for which it is wanted, although water once thoroughly sterilized by prolonged boiling will re-

main free from germs in properly sterilized bottles, provided with properly sterilized stoppers of wool.

It will often be quite sufficient to have water boiled some hours beforehand in clean vessels set apart for this purpose. But for hospitals, a special apparatus for sterilizing water is a decided advantage. That described by Fritsch (fig. 28) has great merits: it consists of a simple kettle in which water is boiled by a gas flame, and can afterwards be quickly cooled down again by means of cold water conducted through a coiled pipe in it.

The apparatus consists of the kettle A provided with a cover D. J is a tap for drawing off the water, W a gauge which indicates the quantity of water in the kettle. At H is a powerful burner over which the kettle is heated. C is the cooling coil through which water flows in at G and out at E. The kettle A is filled with water already warmed, this is quickly brought to the boiling point by the burner H. After it has boiled for ten minutes the flame is turned out and in order to cool it cold water is sent through the heated coil C. Instead of using gas the kettle may be heated by steam, if steam is available, by having a steam pipe introduced into it.

Most large hospitals have a supply of sterilized water in their hot water pipes, if these pipes are properly constructed. This purpose is served by an arrangement such as that in von Bergmann's Clinic for instance, in which large closed reservoirs of water are heated up to boiling point by steam given off from a boiler which is usually at a temperature considerably higher than 100° C. If this process goes on every day and all day, and fresh water is constantly flowing in slowly, the reservoirs hardly cool down at all; and the water in them is always hot if not actually boiling, and so is sure

to be free from germs. It should of course be certified to be so by bacteriological examination.

Quite recently an apparatus for sterilizing water has been introduced by Grove in Germany and Geneste and Herscher in France, by which the water is boiled over a gas flame in the pipes before it is drawn off at the tap. The water flows through a system of pipes over powerful gas burners and is heated up to 100° C.,

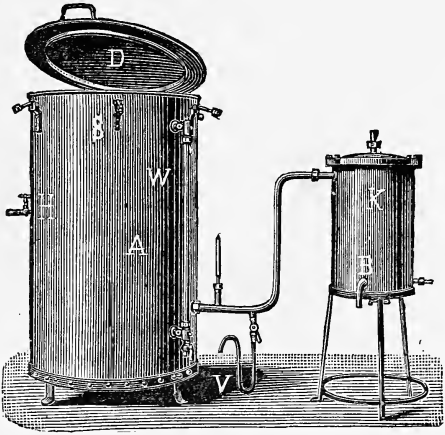

FIG. 29.—Fig. 29 is a representation of Lantenschläger's steam sterilizer in which the tube A by which the steam escapes opens into a condenser K. There it is cooled down by a cooling coil, and it leaves the condenser at B as sterile water.

or higher. It is then collected in a small cistern and from this led through a cooling coil. The coil is cooled by the cold water pipes in which the water that has not yet been heated is flowing, and so two ends are attained at once, the cold water is warmed before it reaches the gas burner, and the boiled water is cooled down. This apparatus is said to provide a very free supply of sterilized water, and to be very economical.

It certainly promises well, but a practical trial is necessary before an opinion can be formed. Steam which has been used to sterilize dressings can also be made use of as a source of sterile water by simple condensation.

The addition of antiseptics to water is simpler and often more convenient than boiling. Water is especially easy to disinfect by the addition of chemical agents, because when it is clear the bacteria that it contains are mostly isolated single specimens, and not collected together in groups or masses that are difficult to penetrate. It is only the turbid water of canals, ponds or marshes, coarse mixtures of obvious decomposing organic matter, that it is difficult or impossible to free of pathogenic germs by the addition of antiseptics. Such water as this must be boiled in order to sterilize it, unless it can be filtered before antiseptics are added to it.

Weak antiseptics, or strong ones in a low degree of concentration, which are generally unable to kill spores of anthrax, cannot of course free water from pathogenic germs. Boric, salicylic and carbolic acid 1·2 per cent. must therefore be prepared with water free from germs, if they are to be used in the treatment of wounds.

A very convenient way of obtaining water free from germs for surgical purposes is by the use of sublimate, first applied to the treatment of wounds by von Bergmann. Geppert's experiments have shown that very resistant anthrax spores will in some cases retain their vitality for more than twenty-four hours even in a 1 in 2000 or 1000 solution of sublimate, and therefore the sublimate solution must be prepared for a longer time than this, from twenty-four to forty-eight hours before use. But even in from fifteen to twenty minutes

sublimate will diminish the number of living bacteria in clear water to an extraordinary degree, and above all will kill off all the dreaded germs of suppuration. It is important to remember this on emergency when boiled water cannot be obtained.

Ordinary water is likely to be rich in alkaline earths especially salts of calcium and these diminish the effect of sublimate. When sublimate is dissolved in ordinary spring or tap water, it is rapidly decomposed the greater part being precipitated in insoluble combinations. According to Liebreich it is not a simple combination that takes place; but there are very numerous combinations formed which separate out as a white precipitate. The addition of acids, such as acetic or tartartic acid, or better still of common salt, prevents the precipitation of sublimate in water. According to Liebreich, Mialhe stated as early as 1845, that the decomposition of sublimate solutions by alkalies could be prevented by the addition of common salt or sal-ammoniac.

Common salt should, therefore, always be added in preparing solutions of sublimate and the amount of salt should be the same as that of the sublimate.

Angerer's pastilles of sublimate and salt were a happy idea; they consist of a gramme of salt and a gramme of sublimate compressed together in the form of a pastille. With one or two litres of water each pastille makes a 1 in 1000 or a 1 in 2000 solution of sublimate. This convenient and portable form of the drug so facilitates its use for disinfecting washing and irrigating fluids, and for preparing an antiseptic surgical solution, that it has already become widely used.

The wide use of sublimate in surgery has frequently been attacked on the ground of the risk of poisoning to which patients or assistants may by carelessness be ex-

posed. Such attacks are best answered by the fact that accidents of this kind do not occur with the most ordinary precautions; in von Bergmann's Clinic, for instance, although for many years sublimate has been most freely used, not a single case of this kind has occurred. The use of sublimate solutions of course can only be allowed under medical control, and the laity should not be entrusted with it; and even the medical man must have studied the pharmacological limits to its use, and must know that he has to be cautious in the use of sublimate on mucous membranes and on extensive wound surfaces. In order to distinguish the colourless solution of sublimate from ordinary water, it is well to colour the sublimate with fuchsin or some other stain.

CHAPTER XIV.

Operating and Sick Rooms.

Arrangement of an operating room in a hospital—In the patient's home—Arrangement of a sick room—Isolation of contagious patients—Disinfection of wards.

In pre-antiseptic times, surgeons operated always by preference in the patient's home rather than in a hospital. This was only natural as it was so constantly their experience that wound infection, which in hospitals so frequently carried off those on whom operations had been performed, occurred far less commonly if the operations had been performed in the patient's dwellings. Pirogoff went so far as to assert that pyæmia and acute purulent œdema, against which he had struggled in vain in the palaces for the sick at St. Petersburg, never gave him any trouble in the wretched huts of peasants in the province of Little Russia. The significance of this observation was at that time little understood. As usual where it was a question of wound infection, it was all put down to the air; the contamination of the air in hospitals by germs of disease was the cause of all the failures in hospital wards and theatres.

Now-a-days we have little occasion to be surprised that the earlier operating theatres were breeding places for wound disorders, when we consider how little stress was laid upon their cleanliness. Any place where patients with infected wounds are frequently treated must become a breeding place for infective germs, if pus and contagious products from the wounds are not

most carefully disposed of, and if the most scrupulous cleanliness is not insisted on in every way.

In Chapter II. we have shown at some length that no special steps need be taken to disinfect the air of an operating theatre, provided only that the stirring up of dust is not allowed to occur; all our efforts must be directed against any chance of infection by contact. An operating theatre should therefore be so planned, and its furniture chosen, that plenty of space is provided and every convenience afforded for cleaning and disinfecting.

It is most desirable that there should be more than one, and at least two operating rooms, one set apart for operating on infected wounds, the other for patients with non-infectious diseases, so that these two classes of cases may as far as possible be kept apart. But there is often great difficulty in carrying this out, space and money, or educational necessities in a medical school may be insuperable obstacles.

If the same room must be used for laparotomy and resections, and immediately afterwards is used for cases of phlegmonous erysipelas, there must at least be great discrimination shown in the order in which the operations are performed. Operations on, and examinations of infected wounds, should always be left to the last, when all patients whose wounds are free from infection are for that day done with.

As to the operation room itself it is in the first place essential that the walls, ceiling and floor, no less than all the furniture, should be easy to clean. A free and abundant water supply is indispensable, and everything should be made of materials that stand washing with soap and hot soda solution, and are not spoilt by having water thrown over them.

Everything which might be an obstacle to cleaning processes of this kind, all ornamentation, as well as joints, recesses and corners, are as far as possible to be avoided, especially in anything in the immediate neighbourhood of the operators.

The floor of a modern operating theatre must be watertight and provided with drainage. It must be possible to wash the walls, as far at least as they are liable to come in contact with men. The flooring is best made of what is called terazzo (Halle Clinic), clay tiles (Royal Clinic Berlin), or Dutch tiles. Asphalt has not proved suitable; it is too soft, and will absorb fluid to a certain extent; cement is too apt to crack, and plaster of Paris soaked in oil, which was at one time tried by Dr. Rotter in St. Hedwig's Hospital at Berlin, wears out too soon. For operation rooms, planned on a smaller scale, linoleum might be suitable, and would last for some time if not submitted to rough wear. For covering the walls very different materials are used. Enamel varnish is often successful, as in Neuber's Clinic at Kiel. Dutch tiles, clay tiles, or the glass plates used in Poncet's operating theatre at Lyons, as well as the opaque glass used in von Schede's hospital at Eppendorf, and marble as in von Schönborn's operating theatre at Würzburg, all make good walls, except that there must be joints and grooves between the different tiles or plates. Lately an excellent substance has been brought into notice for the purpose, the polished white cement made in England. It has been used in the Marienkrankenhaus in Hamburg, and by von Bramann in the Halle University Clinic.

On one side of the room should be everything necessary for washing purposes, with hot and cold water laid on. There must be at least two washing basins. Basins

which are emptied down a sink by rotating them upon an axis, are popular but difficult to clean; fixed basins with a waste pipe at the bottom are better in this respect. The simplest arrangement of all is perhaps that which Neuber has had put up in his private clinic; broad thick plates of glass are let into the wall and on them stand ordinary washing basins, with taps above them to supply them with water. The basins after use

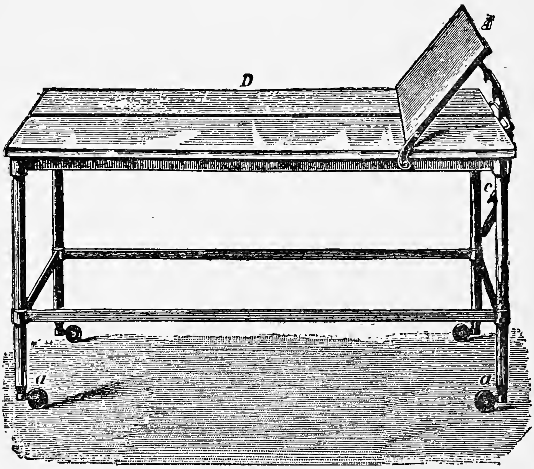

FIG. 30.—A simple operating table designed by Rotter.

are emptied on to the floor, and the water is thus made use of for irrigating the floor. The operation table, the chairs, and the special tables for various special purposes, should all be made of glass and iron, or wood and iron (cf. figs. 30 and 31), so that they can be washed down with soap and hot soda solution, or will stand being sterilized in a large steam apparatus. They must be made as smooth as possible, without joints,

grooves or beading. Upon the operating table in von Bergmann's Clinic there is laid a thick sheet of india-rubber, $1\frac{1}{2}$ cm. in thickness, to protect the patients from pressure, over this is a clean linen sheet which is constantly renewed. Besides this, during the operation the patient has sterilized linen cloths laid under him. Dressing, as already stated in Chapter VII., should, we think, not be kept in the elaborate and expensive cupboards which are now made for them, but should be

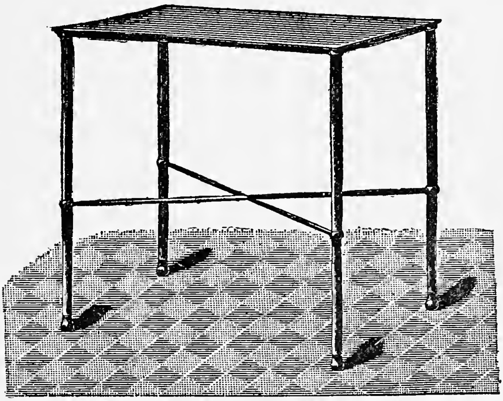

FIG. 31 —Glass table on an iron frame.

stored in cases which can themselves be sterilized. The proper place for the disinfecting apparatus is in the operating theatre, so that disinfection is carried out as far as possible under the eye of the surgeon. A sterilizer for instruments must be set up, not too far from the operating table. The instruments themselves are laid out on glass plates in a cupboard which can be easily kept clean, but it is better to keep them in a neighbouring room than in the operating theatre itself. All the steam-

ing, boiling and washing, that goes on in the theatre, makes the atmosphere there very damp, and however favourable this may be for the prevention of dust, it is not good for the instruments, and is apt to make them rusty. It is a good plan to have a room near the theatre available for splints, extension apparatus, &c. There must also be in the operation room a stand for bottles containing antiseptic or sterilized fluids, and perhaps some arrangement for warming, bowls of enamelled metal or of glass or china for alcohol, irrigation fluids and washing solutions; a few pharmaceutical preparations, such as ointments, triangular dishes for abscesses, and buckets for old dressings and other rubbish. Dressings after being removed from wounds should not be thrown upon the floor but into these buckets. The buckets themselves, as soon as they are filled, are carried away. Some sort of shoot or chimney that can be closed tightly and firmly, should lead from the operating room into the cellar, so that the patient's linen, as well as dirty towels, aprons, bed clothes, sheets and operating coats, may be at once thrown through it into a receptacle set up for them down below.

In a private house it is of course not possible to arrange everything for an operation according to the description just given. But in this case we work under the advantages which we have already said were appreciated by the older surgeons; in a private house the germs of wound infection are not nearly so numerous as in a hospital, and where cleanliness prevails one may even reckon upon their absence. The room should be chosen principally for its light, but apart from this it should be the room which is least inhabited, as the one likely to contain fewest germs according to bacteriological investigations. Many operators have the room

specially prepared, everything cleared out, pictures and curtains taken down, &c. Nothing can be said against this, if it is all done and finished some time before the operation, at least six or eight hours, otherwise it is a questionable measure just before an operation. Any cleaning fills a room with dust and therefore with germs; but this would simply stir up all the dust in the room and load the air with it. If the room is to be cleared out in this way, it should afterwards be shut up for several hours, and the excess of dust allowed to settle again. No cleaning should be allowed shortly before an operation, it could only stir up dust and dirt. Plenty of sterilized cloths must be available, or else towels and sheets fresh from the wash, and recently ironed with a hot iron, may be taken to cover the operating table, and any tables and chairs which are wanted for use.

As to the sick room, the practice of aseptic surgery requires that the greatest cleanliness should be easily carried out in it, as well as that it should be in every way hygienic. In hospitals where the beds are no sooner empty than they are filled again, the standard must be set particularly high. There must be every facility for washing and disinfecting, not only the room, but all its furniture, and for this purpose arrangements similar to those recommended for the operating theatre must be made. Tables, chairs and beds, must be made as far as possible of glass and iron, and floors and walls alike must be covered either with slabs of slate, terazzo or non-absorbent paint. Slate and terazzo have been found in many of the larger surgical institutions a decided improvement on boarded floors; and if the heating arrangements are properly carried out, objections on the ground of coldness may be disregarded.

It should always be borne in mind that no surgical hospital is complete without every possible convenience for baths and shower baths. A bath should be a preliminary for every operation, and in the after-treatment plays an important part in the aseptic treatment of wounds.

The change of dressings deserves special attention. Very often arrangements cannot be made for changing dressings anywhere but in the wards ; if that is so, the dressings must not be changed directly after the morning sweeping, when, as we know, all the dust and dirt in the room is discharged into the air, and the dressings must be taken in order, as we have above pointed out, the aseptic cases first, and infected ones afterwards.

Everything required for the dressing, basins and instruments, must be wheeled from bed to bed on caster tables, and beneath the patients on the beds must be laid waterproof sheets covered with sterilized cloths. But it is always difficult to carry out aseptic principles thoroughly in this way, so that it is far better in large hospitals to make arrangements for all dressings to be done in the theatre or in special dressing rooms. The beds with the patients in them are placed upon a trolly and wheeled to where they are to be dressed. This is very much more convenient in every way, any operative measures that are found to be necessary or advisable during the dressing can be carried out properly, and there are no other patients present, which is another great advantage.

It is almost more urgently necessary that there should be different and separate wards for patients with healthy wounds, and for those whose wounds are infected, than it is to have different theatres. It is as necessary to

keep special wards for septic surgical cases as it is to have them for patients suffering from typhoid fever, or tuberculosis of the lungs. It should be borne in mind that these infective diseases are contagious, and that there is a certain amount of intercourse between the patients in a ward, and that they are all waited upon by the same staff of nurses. The only way to avoid danger is to have separate wards and different attendants for the two classes of cases, those whose wounds are healthy and those whose wounds are infected.

It is not only on general hygienic grounds that it is desirable that wards should not be occupied for long periods of time without a break; it is still more to be desired in the interests of asepsis. At certain definite intervals at least once a year, a thorough disinfection should be undertaken. Any spontaneous outbreak of infectious disease that may occur in a ward, should, it goes without saying, be promptly met by such a disinfection. The number of different methods of disinfecting rooms is so great, that in a short outline like this it is impossible to go into them. But no great confidence can be now-a-days placed in the use of the various chemical agents, the fumigation with sulphur, sublimate, bromine and chlorine, or the sprays of carbolic, sublimate, creolin, &c., knowing as we do that the germs of wound-infection cling to objects and the walls of rooms enveloped in dirt and particles of pus. Disinfection is most effectually carried out by the means most employed for other purposes in the aseptic system. At the head of the list must come thorough scrubbing and washing with soap and water. Everything that can be washed, is washed with hot water and soda; paint is renewed, and walls, if not repapered or whitewashed, rubbed with bread as recommended by Es-

march; and such things as beds and curtains are sterilized by steam.*

* In von Bergmann's Royal Clinic the walls and ceilings of the newer "pavilions" are painted with bright oil colours, the floors laid with flags. The bedsteads and other furniture are made of wood or iron so that they can be washed. When a "pavilion" has to be disinfected it is carried out thus:—Floors, walls, ceiling, bedsteads, windows, doors, &c., are energetically scrubbed with soap, soda and water, as hot as possible, and then rinsed. All beds and linen objects, as well as window curtains, are sterilized in steam. Playthings are destroyed. The "pavilions" then remain at least six or eight days unused, and are thoroughly aired with all the windows open day and night.

CHAPTER XV.

Aseptic Operations and Wound Treatment.

A description of an amputation of the breast by von Bergmann—The preparation of the patient; of the instruments; of the assistants—The operation itself—An aseptic chloroform mask—The treatment of the wound—The importance of hæmostasis and drainage—Irrigation with aseptic solutions not necessary—Suture and plugging of the wound—Temporary, permanent, and repeated plugging—The principal points to be attended to in dressing the wound—The dressing should not as a rule be disturbed till the wound is healed—The conditions under which the dressing should be changed.

A clear idea of an aseptic operation and the aseptic treatment of the wound will be most simply arrived at, if we start by taking a typical example, and describe how von Bergmann performs amputation of the breast.

Let us suppose that the patient is waiting for the operation at 2 p.m., when the clinical demonstration is held.

The patient has nothing to eat or drink after coffee at 8 a.m., so that her stomach shall be empty and no vomiting occur under chloroform. Vomiting, besides introducing unpleasant complications, may interfere with asepsis by the vomit getting on to the field of operation. Shortly before the operation, the patient has a warm bath in which her whole thorax and the arm on the same side as the disease is soaped with especial care. The armpit is shaved during the bath, and the patient is afterwards put into a bed with freshly

washed linen. She is then taken into the operating theatre in the bed.

Meanwhile dressings and gauze sponges have been sterilized in the steam sterilizer in cases with closely fitting lids, and the closed tin cases with their freshly

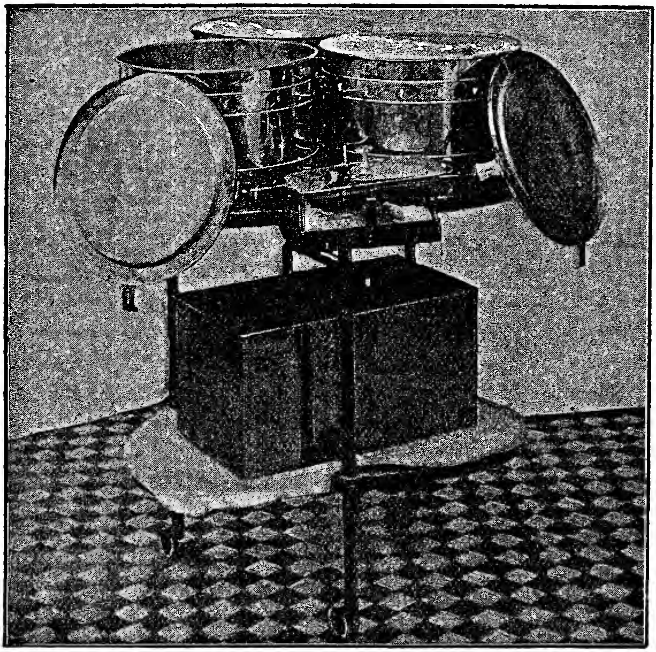

FIG. 32.—Gauze, cotton-wool, and bandages, each sterilized in a separate case The cases open ready for use, are placed upon a table which is covered with a sterilized linen cloth.

sterilized contents are put ready upon tables which are covered with sterilized linen cloths. First of all a case containing only gauze sponges is drawn up to the operating table. The gauze sponges, made out of squares

of gauze ten cm. each way, are placed separately into the case before sterilization, so that they can be quickly and easily taken out as required. The case is not opened till the operation begins, and the sponges are

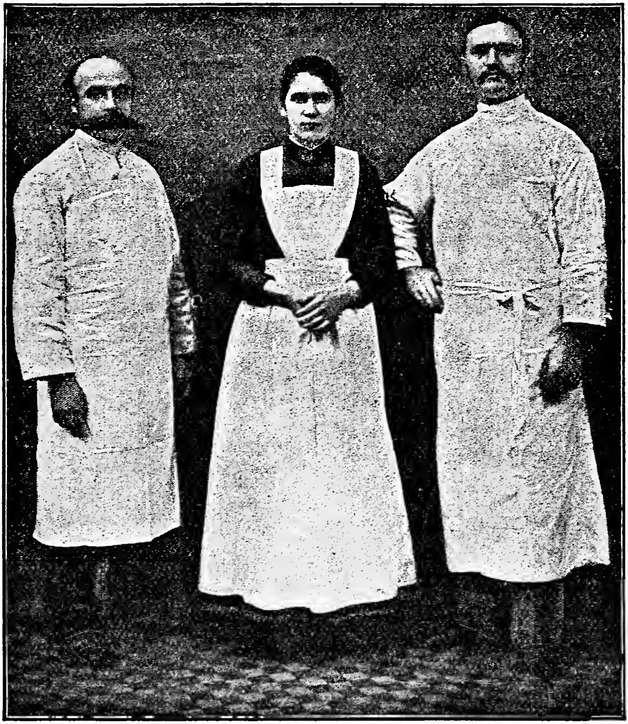

FIG. 33.—Dress of Surgeon and Nurses in von Bergmann's Clinic.
Male Nurse. Nurse or Sister. Surgeon.

wanted for use; the sponges are then handed to the operator or assistant by the sister. Three other closed cases are set in readiness on a table in the background,

the one filled with gauze, the second with rolled cotton-wool, and the third with calico bandages; these are wheeled up and opened when the operation is finished and the dressing is about to begin.

Before the patient is put on the table, the instruments are selected, put in the wire basket, and with this placed in the soda sterilizer which is quickly set in action and boiled.

During the operation they lie in shallow dishes filled with one per cent. solution of carbolic and soda, in which they have been placed in the baskets.

Vessels containing catgut, silk, drains, &c., stand within easy reach of the operation table.

Meanwhile the operator, dressers, and other assistants have also prepared themselves. The surgeon and his assistants put on for the operation long coats of white linen which have been sterilized in steam shortly before.

Sisters and nurses wear dresses made of washable linen material, sisters white aprons, and nurses linen jackets as well as aprons. All alike have their arms bare at least to the middle of the forearm, and everyone directly concerned in the operation has to disinfect his or her hands most thoroughly, according to the directions given in Chapter V.

The patient is now lifted on to the operation table, is anæsthetized, and then covered with a large, sterilized, linen sheet, under which she is freed from all other clothes or wrappings.

The disinfection of the field of operation is now commenced. The breast, neck and arm are energetically scrubbed by means of brushes with soap and water as hot as possible. The skin is then rubbed with dry cloths, which have of course just been taken from the

sterilizer, and finally the skin is washed with alcohol and sublimate. The patient thus cleansed is again put upon fresh sterilized cloths, and wrapped up in them in

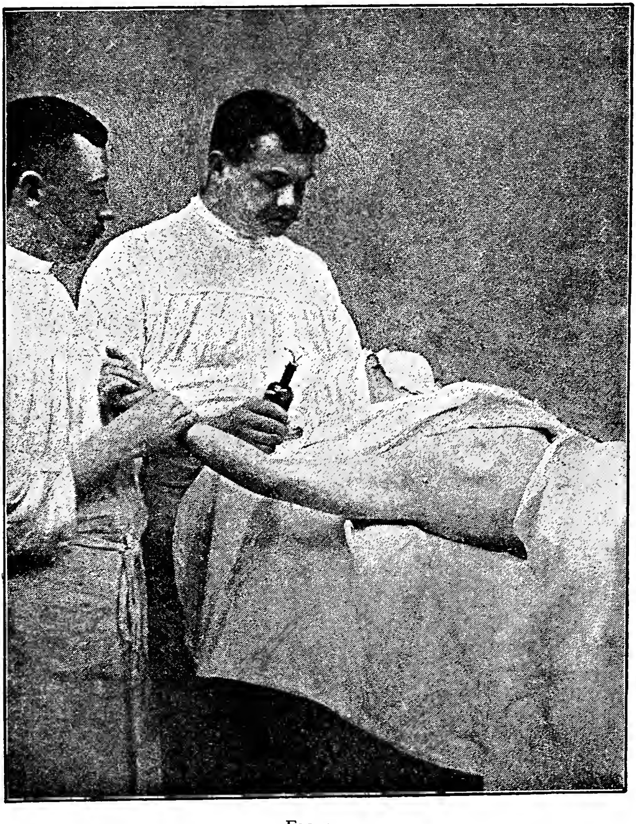

Fig. 34.

such a manner that one cloth limits the field of operation below, while it covers the abdomen and legs, and another lying over the neck and the other side of the

chest bounds it above. The patient's hair is done up with a sterilized bandage, which, to make it adhere more firmly and prevent it slipping, has been moistened with sublimate solution.

One assistant gives chloroform, another holds the arm, and one or two help the operator. One sister has to hand instruments, the second hands sponges and dressings.

When the operation begins every spurting vessel is seized in artery or catch-forceps at each cut, and capillary bleeding is stopped by pressure with gauze sponges. When the breast is removed and the axilla has been cleared out, the vessels caught in the forceps are ligatured with catgut. The whole surface of the wound is then held open with retractors and most carefully examined to see if any bleeding vessel has not yet been ligatured: even the smallest bleeding points are cautiously seized, isolated and ligatured.

The great wound is for the time closely and firmly covered with gauze sponges and the flaps of skin brought together, in order that with the wound thus temporarily closed, the surrounding skin may be cleansed of blood with gauze and sublimate and then dried. If the cloths on which the patient lies are saturated with blood they are renewed. The wound is then again inspected to see that there is no bleeding. When the whole wound is absolutely dry, the skin is united by silk sutures without any previous washing with aseptic fluids. Where pockets are formed and the skin does not lie quite flat, as is especially the case under the latissimus dorsi and on the front of the thorax, one or two drainage tubes are put in as may be needed. Finally the skin is once more wiped dry and the dressing is applied. This should be done so

as to press the surfaces of the wound lightly together; in the axilla, where this is especially necessary and the skin will be seen hanging down like a bag, balls of gauze are one after the other pushed in so as to exert a light but uniform pressure upon all parts of the skin over the emptied space, and the original form of the

FIG. 35.

space, properly described as that of a hollow pyramid, is completely restored. Twenty thicknesses of gauze are laid over the whole line of suture and beyond this over the whole of the front and side of that half of the thorax, which has been operated upon. Rolls of soft

absorbent wool are opened out over this, and a bandage holds all firmly in place. The arm from the fingers to the axilla is bound up with wool and bandages, and then the forearm flexed at an angle of about 60° with the upper arm, is pressed against the dressings over the thorax, with about the same amount of pressure as is used by the patient in holding a thermometer in the axilla. The space between the arm and the axilla is filled up with pieces of gauze and wool; and strips of wool are also laid round the neck, and from the neck down the side of the chest. In this way the thorax, arm and neck, are all included in one continuous dressing, which completely shuts off the field of operation from all communication with the exterior.

This dressing remains on eight days and is then taken off. If the result is as desired, union will have taken place along the line of incision and some of the sutures can be removed. The drainage tubes are taken out, and a new dressing is put on but this time a lighter one, no longer compressing but merely protective, this is left on until the wound is finally healed and the patient discharged from five to eight days later, according to the severity of the operation and the condition of the patient. The channels in which the drainage tubes lay are lined by good red granulations, and their smooth walls are so elastic that they immediately come together and heal up.

For our present purposes an operation may be considered in five stages:—

1. The preparations for the operation.
2. The operation itself.
3. The care of the wound.
4. The application of the dressing.
5. Subsequent dressing till the wound is healed.

The preparations include the preparation of the patient, of all that is necessary for the operation or dressing, and of the staff of assistants.

The preparation of the patient is not always such as we have described for amputation of the breast; sometimes a much longer time is required, sometimes a far shorter time is all that can be allowed. If the region of the body to be operated upon is eczematous or the site of neglected ulcers, the eczema will have to be cured and the condition of the ulcers improved by suitable treatment, to facilitate as far as possible the carrying out of aseptic principles. In operations on the alimentary tract purgation and irrigation of the stomach form a part of the preparations, which is of the greatest importance in cases of excision of the rectum or resection of the intestine or stomach.

But in many cases a thorough preparation is impossible. Operations such as herniotomy allow of no delay, and a compound fracture calls for immediate dressing. Accident cases cannot be given baths; but all the more attention must be bestowed upon the disinfection of the body by a thorough soaping and rubbing, and the use of alcohol and ether as well as sublimate.

Especial stress must be laid on surrounding the whole field of operation with sterilized cloths, and placing others beneath the patient. They are a protection against the accidental contact of the surgeon's hand or of some instrument with parts about the wound which have not been disinfected. They are safeguards in the first rank of importance, which enable the surgeon to lay down his instruments, or to support his hands and arms, and to do away with the dangers of spontaneous movements on the part of the patient. For this purpose formerly it was customary to use

pieces of mackintosh or some other waterproof material, which will not stand disinfection by heat, and can be disinfected only by the uncertain methods of washing with soap and antiseptics. Decided preference should be shown for linen cloths freshly washed and sterilized in steam.

It would set the surgeon's mind at rest and be a great advantage if the disinfection of everything used in an operation could take place immediately before it, and all the measures for securing asepsis were carried out under his own eyes. But this is only possible in the case of things like metal instruments, which can be rapidly disinfected as soon as some soda solution has been made to boil. But at the same time the metal instruments are just those things which it is most desirable to have disinfected only the last thing before the operation; since it is generally only just before the operation that the necessary instruments can be put together. There will not usually be time enough to prepare immediately before the operation whatever has to be sterilized in steam, dressings, gauze for sponging, linen cloths, &c.; because getting up steam, saturating the dressings with it and effecting complete disinfection takes altogether about an hour. These things and others which require longer preparation must always be kept ready for use. No doubt the more recently the steam sterilization has taken place the better. But several days may elapse between the sterilization and the operation, if only proper precautions are taken to protect the dressings from infection in the interval, by keeping them in suitable boxes that have been sterilized.

The preparation of the staff of assistants for an operation, whether in private or in hospital practice, is still very differently carried out under different surgeons.

Many attach no importance to scrupulous cleanliness, while others exact of all concerned that they should have a complete carbolic or sublimate bath. The former are as culpable as the latter are absurb.

Strict personal cleanliness should be observed by any one taking part in an operation, and every convenience in the form of baths should always be afforded for this purpose. After this clothing requires special attention, as next to the hands it takes up most germs. Every surgical clinic should therefore be provided with its uniform of long coats and aprons, and an abundant supply of these should be at the service of the operating staff. It is a first principle that neither operator nor assistants should wear their ordinary clothes; each one must have a special dress. The large aprons of mackintosh or oiled silk, which have been so commonly used for this purpose, are not really suitable, because as we had occasion to mention in describing the preparation of the patient, they are difficult to keep free from germs. Aprons of linen and long linen coats which are sterilized with steam before each operation are the best.

As to the operation itself, a few words upon the administration of the anæsthetic are desirable. It is, on aseptic grounds, very important that this be judiciously done, for asphyxia during the operation is a common excuse for neglecting aseptic measures, which is no doubt justified when every second is precious, although the consequences of such neglect are generally conspicuous. The head and mouth of the patient must of course be held as far as possible from the wound so that nothing may be vomited, coughed, or spat upon it. In an amputation of the right breast, the patient's head and face are to be turned towards the left. Neither is it too much to require that some attention be paid to the

apparatus used especially the mask, and especially in operations on the mouth and face. Erysipelas or diphtheria could easily be conveyed by infected chloroform masks and gags, to say nothing of the infective influence on wounds of apparently healthy saliva, and the cleanliness that is always necessary in this situation. Gags and tongue forceps may be boiled in soda solution with the other instruments before each operation, and the author has designed a mask, the wire frame-work of which can also be boiled, and which can be conveniently provided with a new covering of sterilized gauze each time it is used.

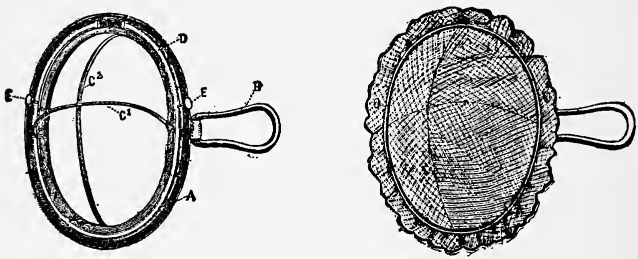

FIG. 36.—Aseptic chloroform mask (Schimmelbusch).

The old fashioned chloroform masks, to say nothing of more complicated anæsthetic apparatus, could only be cleaned with considerable difficulty, even Esmarch's and Skinner's widely used apparatus, consisting of a wire frame and covering of some cloth, are by no means easy to keep clean. The cover must fit well, and to use a new one for each administration would be too expensive; and there is an objection to frequently washing and disinfecting the cloth cover, as it gradually shrinks and the texture gradually becomes closer and more impervious to air. In the administration of

chloroform this is a matter of some importance, as the dilution of the chloroform vapour with air is impeded and the danger of asphyxia thereby increased.

In the mask described by the author the framework is covered with any piece of gauze of the right size, and preferably six or eight layers thick; the covering can therefore be quickly and early renewed whenever the mask is used. The mask consists of a ring of the proper shape to fit the face, in which there is a deep groove; attached to this ring is the handle (B) which can be turned over. The curved wires C^1 and C^2 are fastened to the ring so as to cross each other diagonally and can be turned up or down. The wire D, which is held by a spring in the groove in the ring A, can be raised out of the groove by the handles EE, the curved wires C^1 C^2 are made so that when they are turned up, they catch where they cross; the wire D is raised from the groove, several thicknesses of gauze are laid over the frame, and the wire is brought back over the gauze, and by means of the spring which presses it into the groove stretches the gauze tight and fixes it. The superfluous gauze is then cut off with scissors not too close to the ring.*

In the course of the operation all that is necessary is to maintain the aseptic conditions, under which it is thus undertaken. Much can be done by operating quietly and without hurry; but a carefully trained staff of assistants, and one that when the eyes of the surgeon are turned away can still be relied upon to carry out his instructions precisely, is what is needed most of all. Should it be necessary to temporarily interrupt an operation, gauze is held over the wound so as to keep it carefully covered.

* The mask is made by the firm Jetter and Scherer and can be obtained of all instrument dealers.

No less important than the exclusion of germs as an aid to rapid healing is the treatment of the wounds. Everything must be arranged in the manner most likely to promote healing and prevent the development of microbes.

Often the tissues are infected from the first, or we have to operate on regions of the body in which infection with germs is unavoidable, such as the mouth or intestine. But even where thorough disinfection appears possible as in amputation of the breast, we should not rely solely upon the perfect working of aseptic appliances. Anyone who knows anything of bacteriological investigations, knows what extraordinary care is required in manipulating nutrient solutions in order to avoid unintentional infection, and how in spite of all precautions infection nevertheless will often occur. The exclusion of absolutely all germs at an operation, into which so many unavoidable complications enter, can hardly be reckoned on with anything like certainty.

There is no doubt that extensive operations by means of strict asepsis can be successfully performed, without any particular attention being paid to the blood and discharges from the wound, the skin being firmly and completely sewn up as soon as all coarse hæmorrhage is arrested; that healing takes place naturally under these circumstances is proved by severe subcutaneous injuries such as simple fractures. But the absolute freedom from germs, which is guaranteed in such subcutaneous injuries, is unattainable in wounds made by the knife; and uninterrupted healing, natural in simple fractures, cannot be safely counted upon even with strict asepsis, where the skin has been divided and the door opened to the germs of infection.

Experience teaches that three conditions are particularly favourable to the infection of wounds:—

1. The presence of blood in the wound cavity.

2. The collection of wound secretions.

3. The presence of loose or badly nourished pieces of tissue.

By avoiding these we do much to prevent wound infection.

There is no point upon which the difference between ancient and modern views is more striking than with regard to the significance of blood and secretions in a wound. The ancients regarded them as plastic material from which the injured or missing tissues were regenerated and the scar was formed; to us they appear as irritants, stimulating the formation of new tissue, often retarding the progress of healing, and increasing the risk of infection. We no longer believe that tissue cells arise spontaneously in wound secretion, nor that blood organizes and is converted into living tissues; we know that healing proceeds from none but the actively growing tissues of the body, and that repair is hindered by everything which delays the coming together of such tissues. Blood exudation, and pieces of dead tissue are so much lifeless organic matter, which so long as it is uncontaminated, the healthy body absorbs slowly but without taking harm, but which is all the time the most fertile soil possible for pathogenic germs, and when decomposed produces the most severe wound diseases.

It is therefore of the first importance that all bleeding in a wound should be carefully stopped; that discharges should be drained away, and that the wound surfaces should be smoothly and cleanly cut and not mangled. Ten years ago von Bergmann declared that "the sur-

geon who does not most carefully stop all bleeding, will reckon in vain on the results and consequences of his antisepsis," and the experience of subsequent years has not led to a change of our views.

The most minute and careful arrest of hæmorrhage is reckoned in von Bergmann's Clinic as most essential for rapid and certain healing. In the most trifling operations the same care is taken as in amputation of the breast, and no wound is closed until the operator is convinced by repeated examination and scrutiny that even the smallest bleeding vessel has been ligatured with catgut, and that the wound is absolutely dry. All deep wound cavities are drained. Circumstances in each case must determine the manner in which this is to be carried out, whether counter-punctures are needed, and whether the skin should be tucked in and invaginated for this purpose. Drainage can only be dispensed with when by sutures, by dressings, or by the tension of the tissues, the wound surfaces can be so exactly adjusted that no retention of discharges is possible. When there is any doubt, we should remember how little a drainage tube disturbs or delays the healing of a wound, and what risks are run by omitting to drain a wound with deep irregular recesses. We have to weigh in the one case a day or two's delay in healing against an addition to the risks of infection. In all cases if the skin be allowed to close over collections of blood and exudations, the temperature rises; and even if the exudations be at once liberated, healing is delayed.

To ensure a clean cut wound, without mangling of the tissues it is often of the first importance that incisions especially in the skin should not be made too small; and it is an important general rule that hæmorrhage can only be accurately arrested in well exposed, open wounds.

How in any particular operation the tissues may be most spared from injury, hæmorrhage arrested, and drainage provided for, does not come within the scope of the present work to discuss: all this the surgeon must learn from practical experience.

Accurate closure of the wound has been described as an antiseptic measure of the first rank; and rightly, for a closed wound is safer from infection than an open one, and every day progress is made which diminishes the danger of infection. But in order that suturing a wound may have this effect, the surfaces must not only be healthy but so accurately adjusted that there is no room for any foreign element between them. Nothing is attended by more direful consequences than closing up a wound in the depths of which there are infective germs embedded in blood and exudation. The worst thing that can be done for such a wound, and the surest way of promoting infection, is to suture it.

Where infective germs cannot be prevented from reaching a wound, where hæmorrhage cannot be completely arrested, or the operation must be performed in tissues that are already infected, no attempt must be made to close the wound, and it must be either simply covered with a gauze dressing, or plugged with a tampon of gauze.

Here again, it is difficult to lay down any hard and fast rules for all cases. We shall confine ourselves to the general principles on which the plugging of wounds should be carried out.

In von Bergmann's Clinic plugging is made use of in three different ways; sometimes it is (1) temporary and soon dispensed with, sometimes it is (2) permanent and not disturbed for days, and sometimes it is (3) frequently renewed.

Iodoform gauze is practically always used for this purpose. In the first case the operation wound is plugged in its whole extent with strips of iodoform gauze, and the gauze is left in the wound forty-eight hours, it is then removed, and the wound if it looks well, is treated as a fresh one, that is, it is drawn together and sewn up. As a rule a wound which has been plugged with iodoform gauze for two days, provided that it was not already infected, looks fresh, not in the least irritated, and just like a dry wound immediately after the operation. Such a wound after being plugged for forty-eight hours heals exactly as if it was a fresh one.

The chief use of a temporary tamponade is to prevent the parenchymatous bleeding which occurs whenever large capillary regions are opened up as for instance in the resection of bones. In such a case, the gauze which is for the time pressed against the bones, prevents the oozing of blood until thrombosis has closed the vessels. It is also valuable when the surgeon is not sure that the wound is aseptic.

The permanent tamponade of iodoform gauze, which may often be left in a wound eight, ten, or even fourteen days, serves first of all to arrest hæmorrhage which cannot be stopped after two or three days, such as for example hæmorrhage from the great venous sinuses of the brain. The only way to control bleeding from the intra-cranial sinuses is to place at once a tampon of iodoform gauze on the bleeding place, and let it lie for at least eight days, until by the adhesion of its walls, or by firm thrombotic clots, the sinus is securely closed. Tampons are also left undisturbed for days when it is desired to provide a protection for large wounds of the soft parts, over which infective matter would be continually or frequently discharged. They are indispens-

able for instance in dressing excisions of the upper jaw, resections of the tongue, excisions of the rectum, &c. A tampon of iodoform gauze pushed into the cavity after excision of the upper jaw, can be in this way very firmly fixed in the wound so that no further steps need be taken to secure it, and it usually can be left for ten days without decomposition of the wound secretions taking place in it.

Tamponade may be repeatedly renewed when infected wounds have to be kept open, because the results of the infection cannot be put a stop to for some time. This is the case often in phlegmonous erysipelas especially when sloughs are in process of being thrown off. When the discharge is excessive, the pus thick and tenacious, and the wound of any depth tamponade is not satisfactory, and it is advisable, as soon as the hæmorrhage of the operation has been arrested by the first tamponade, to employ india-rubber drainage tubes as a better means of conducting away the secretion.

One of the most crucial points of difference between the present treatment of wounds in von Bergmann's Clinic and that practised elsewhere, is that wounds are no longer irrigated with antiseptic fluids either during or after the operation, or when the dressings are changed.

The credit of having first called attention to this dry treatment of wounds as it is called, belongs to Landerer (1889). This method of treatment was first adopted for isolated cases in von Bergmann's Clinic about three years ago, and very soon came to be constantly employed in consequence of its advantages.

Even earlier than this, the plan of squirting antiseptic fluids on to wounds, the fluids being conducted under high pressure from elevated reservoirs by means of india-rubber tubes, had been abandoned, and the

wounds were merely washed with an irrigation fluid which was carefully poured over them from a small can. Vigorous syringing, especially when the wound is infected, may reasonably be charged with not merely washing away pus and infective matter, but actually forcing it into the interstices of the tissues, and so perhaps spreading rather than diminishing the infection.

If we look back into the history of the introduction and growth of this practice, we are obliged to confess that it never was securely founded upon experiment and experience, but was from the first the outcome of hypothesis and credulity. The necessity for wound irrigation was an article of the faith, just as the carbolic spray had been for some time before it.

It was always presumed that by means of antiseptic irrigation a wound could be disinfected, and this idea was handed on by tradition undisputed and uninvestigated. A moment's consideration of the disinfectant powers of antiseptic solutions, and the conditions under which they had to act in a wound, should have made us sceptical as to whether antiseptic irrigation could achieve what it was asserted to.

No more unfavourable conditions for the action of antiseptics could be imagined. The successful employment of chemical disinfectants depends on three essential provisoes, none of which are satisfied in this case; the chemical must be able to penetrate the substance to be disinfected, must not be altered by any chemical reactions, and must have a long time given it to act in. In infected wounds that are freshly made, and still more in old ones, the infective germs, cocci and bacilli, are always embedded in blood clots, shreds of tissue, scabs and crusts, if not in the interstices of the tissues themselves, and none of the antiseptics, least of all carbolic

acid and sublimate, are able in weak solution to penetrate these structures and reach the micro-organisms. Moreover, the albuminous fluids in the wound at once enter into combination with the antiseptic, and diminish or completely annul its efficacy, and the short time for which the pus organisms are bathed with weak antiseptic solutions is quite insufficient for their destruction.

Moreover, while the wound is most certainly not disinfected, it most certainly is injuriously acted on by irrigation with antiseptics; for all antiseptics are poisonous. It must be admitted that the tissues exposed in the wound are much more liable to be affected by the poison than the cocci and bacilli, and that the tissue cells are more easily killed than the infectious germs, most of which are far more resistant. Proof of this can always be seen after irrigating a fresh wound with a three per cent. solution of carbolic acid; the surfaces of the wound no longer look red and bathed in blood, but have a whitish appearance and are covered with small grey particles of superficially necrosed tissue. In any case all antiseptic irrigation stimulates the wound to excessive secretion, and sets difficulties in the way of healing. It is well known that irrigation of wounds frequently leads to general poisoning, often of a severe form.

The merit of antiseptic irrigation, which cannot be disputed, is that it removes blood and pus, and introduces into the wound agents, which even if they cannot kill every individual organism can check the development of bacteria.

For the removal of discharges a perfectly unirritating fluid, such as sterilized normal (·75 per cent.) salt solution or weak solutions of boracic acid, answers decidedly better, and better still is simple sponging with some absorbent material, such as gauze. In von Bergmann's

Clinic in all operations, whether the parts be infected or not, as well as at the subsequent dressings, blood and secretions are removed by sponging with pieces of gauze. Only rarely is use made of one of the above mentioned indifferent irrigating fluids, when the discharge from a wound is unusually profuse.

How imperfectly the development of bacteria or of their injurious effects is checked in wounds by carbolic or sublimate irrigation, is proved by clinical experience. The growth of the bacillus pyocyaneus in a wound which is covered with green pus, cannot be arrested by even long continued irrigation with a solution of sublimate. A better application for controlling or rendering innocuous the proliferation of bacteria, at least in fresh and simply purulent wounds, is iodoform. Just as in a dressing iodoform delays the decomposition of absorbed secretions, so too upon the surfaces of a wound it has most valuable antiseptic properties, and that without injuring the tissues or increasing the discharge. How iodoform acts antiseptically in wounds is not as yet fully explained, that it does so is beyond all doubt. According to the investigations of Behring and de Ruyter, it acts more particularly on the metabolic products of bacteria. A still better dressing than iodoform gauze for wounds with a copious discharge of foul pus is gauze wrung out in liquor aluminii acetici (one per cent.), and incidentally it may be mentioned, that no antiseptic acts so energetically as this solution against so-called blue suppuration.

We have already pointed out (Chapter VIII.), how aseptic dressings should be arranged to protect a wound from any further infection until it is completely healed. The points on which stress was laid were, that the dressing must surround the wound with a covering that

is free from germs, that this covering must absorb the discharges, and that it must prevent their decomposing. It is equally important that the wounded part should be kept at rest and in good position, and that the wound itself should be subjected to gentle pressure. We must provide against the healing process being disturbed by mechanical conditions, and should see that the position of the part as well as the pressure of the dressing, help in bringing the wounded parts together and so promote their healing.

A further important end is served by pressure on the wound, in that it prevents collections of blood and discharge forming, and so enables us to attain the object aimed at in the careful arrest of hæmorrhage, and in measures for the establishment of drainage.

Lister used to change his dressings at first every twenty-four hours, and when possible twice; and in fact this was necessary, for the layers of wet carbolic gauze and the waterproof covering, acted just like a Priessnitz, *i.e.*, a hydropathic compress, or the French "compresses échauffantes." Under the warm moist covering, in spite of the carbolic acid, bacteria developed rapidly in the discharges, and the irritating action of the carbolic and of the warmth upon the wound caused the exudation to be much more active, in spite of the silk protective—disinfected oil silk—which was laid over the wound. The dressing was soon saturated with exudation, because it had to absorb more of it than a dry dressing has, and what was absorbed was not allowed to evaporate.

By the use of absorbent dressings we are enabled to leave a dressing on for a long time, in fact, unless the discharge is unusually free, till the wound is healed.

Every time the dressings are changed fresh risks are

incurred, and the comfortable position of the parts, as well as the pressure on the wound, are disturbed and altered. The way in which the temperature of patients suffering from acute or even chronic suppuration of a joint is sent up by each change of the dressings is most striking. A rule should be made that a properly applied absorbent and aseptic dressing should not be removed till the wound is healed, unless either

1. The dressing is no longer able to take up the secretions of the wound, or
2. The dressing is soiled from the outside, or
3. Drainage tubes and sutures have to be removed, or
4. Signs indicating infection are manifested.

A dressing of gauze or moss takes up discharges from fresh wounds in the most satisfactory way. If the discharge comes through the dressing at one or two spots, the aseptic character of the dressing may usually be maintained by covering it with some more of the dressing, or by allowing the air to get at and dry the parts that have been moistened. If the dressing is completely soaked by the discharge the superficial layers should be renewed, whilst the deep layers remain untouched. With a foul suppurating wound, the dressing should be changed oftener, since thick pus is taken up with difficulty, even by gauze, and soon collects under the dressing; in such cases we may have to change the dressing as often as every 24, 12, or 8 hours, when the discharge of pus is abundant.

We have to provide against dressings being soiled from outside, particularly in the neighbourhood of the rectum and genital tract. When a dressing gets soaked with urine or contaminated with fæces, the soiled parts must be renewed at once.

Drainage tubes in von Bergmann's Clinic are removed

in from six to eight days. By that time, as a rule, the deeper parts of the wound have united, and even the skin incision is almost healed, so that the majority at any rate of the sutures can be removed. The whole of the drainage tube is removed at one time, it is not merely shortened and again replaced. The small fistulous passages which are left on removal of the drains, close in the course of a few days. The removal of a drain is necessary at the end of a week, because there is then no longer any discharge for it to conduct away, and it merely hinders the complete closure of the wound cavity, but there is not the slightest danger in leaving a drain for much longer. Drainage tubes have from oversight, sometimes remained in wounds nearly five weeks in von Bergmann's Clinic, and in spite of this, no special disturbance has occurred, and the wounds have healed quickly in their whole extent when the tubes were removed. The removal of drainage tubes is most simply and satisfactorily carried out by changing the dressings. The plan of using drainage tubes long enough to reach through the whole dressing, and that of fastening long threads to them, so that the tubes may be removed after a few days by pulling them or the threads attached to them without removing the dressing, are not to be recommended, as they destroy an essential feature of the aseptic dressing by establishing direct communication between the wound and the outside.

The frequent change of Lister's dressings was formerly to some extent justified, because surgeons, especially during the first few days, had to find out how the wounds were progressing, and to make sure that no infectious diseases were developing. Of course it goes without saying, that as soon as there are signs of infec-

tion in a wound the most energetic measures are to be taken. All or the greater number of the sutures should be at once loosened, the wound opened widely and plugged or drained with iodoform gauze. The use of the modern permanent dressings of course makes it impossible that the wound should be directly watched, and it becomes the more important that the surgeon should have studied the symptoms, other than the appearance of the wound, which indicate the onset of infection.

In the first place he should know what the signs and symptoms of normal healing under aseptic conditions are.

We will describe the course taken by such an operation as the amputation of the breast with which we opened the chapter. On the day of the operation sensitive patients will complain of pain. But on the day after real pain as a rule ceases under aseptic conditions, and there is nothing more than perhaps a feeling of discomfort due to the dressing, and that only in patients of high sensibility. As soon as the effects of the chloroform have passed off, usually on the day after the operation, vomiting and headache cease, and appetite and sound sleep return. On the second day after the operation all troubles have disappeared and patients feel quite well.

The assumption is often made that when a wound goes on well under Lister's dressings patients generally have no fever. This however is not correct. Every experienced surgeon will subscribe to what Volkmann says:—"We shall not be far out in saying that of 1000 patients undergoing operations of any gravity, and adequately treated on antiseptic principles, only one third will have no fever, another third will have moderate, and the rest high fever."

This so-called aseptic fever often gives rise to a temperature as high as that of septic fever 39° C. to 40° C. (102° F. to 104° F.).

Almost all major fractures run a course that is typical of aseptic fever. Von Volkmann observed a series of 14 successive simple fractures of the thigh treated in his clinic. Most of them had for several days a temperature of 39° C. (102·2° F.) to 40° C. (104° F.); in two cases it lasted for 10 days, in one case for 11, and in another for 16.

Aseptic fever sets in immediately after the operation; if the operation occurred in the morning the patients often have a temperature of 39° C. (102·2° F.) on the evening of the same day; frequently the temperature rises by degrees from the day of the operation, and then slowly falls. Fever which does not begin till the second or third day after the operation is practically never aseptic; it is a sure sign of infection. As a rule when the wound does well the temperature returns to normal in two or three days, yet exceptionally it remains high for a longer time, and then it almost always falls gradually day by day after a quick ascent at the commencement.

It should be clearly understood that what is called aseptic fever has nothing to do with the aseptic course of the wound. No less than septic fever it is due to absorption, the absorption of the ferments produced by the death of the injured tissues in the wound. The whole phenomenon is caused by loose shreds of tissue, extravasated and coagulated blood, and fibrin ferment (von Bergmann and Angerer). This also explains why the fever sets in immediately after the operation, therein differing from septic or infective fever. The cause of the aseptic fever, fibrin ferment, is present as soon as

the blood is poured out or the tissues are destroyed; the ptomaines and poisonous substances due to bacteria, which when absorbed excite septic fever, are formed slowly and only after the germs that have gained access to the wound have had time to multiply enormously. The presence of a germ or a number of germs in a wound does not at once become evident by constitutional disturbance; suppuration, fever, and all the effects of bacterial toxines only show themselves when the toxines are produced in large quantities. In every case of wound infection a certain incubation period must be passed through, and marked symptoms can hardly ever be expected before the second day.

The prognosis, therefore, cannot be decided by the first day after an operation, and it is not till the second or third day that we know how we stand. Neither need we have any fear of signs of infection occurring after this. If on the second day there is no disturbance in the general health of the patient or in the wound, we may generally regard it as proved that no infection has occurred during the operation, and we may feel secure of a favourable course for the wound. Only very seldom do the signs of infection develope still later under permanent dressings; and in these cases we must, in the light of so great an uniformity in the dates, assume that infection has taken place under the dressing and not at the operation.

The first signs of wound infection are both local and general (fever). The objective local signs of inflammation, redness and swelling, are at first concealed from us by the dressing, and this we do not wish to disturb if possible. But pain felt by the patient is on the other hand often very significant. Inflamed wounds almost always cause violent pain, and if the patient has not

complained of pain on the day of the operation or the first day after it, such a complaint at a later date is all the more significant. Again, although we cannot get at the wound itself to examine it, more distant parts in relation with the wound we can examine, and from our examination draw important conclusions. Nothing should be more carefully observed than the lymphatics, and a suspicion of infection should make us at once feel whether the lymphatic glands likely to be affected are swollen or not.

A schematic description of the constitutional disturbances, fever, &c., caused by septic infection, cannot be given here. Septic infection is caused by a number of different organisms, which produce different toxines and affect the body in different ways. In fever which is not due to infection, the disturbance varies with the amount of blood poured out into the wound, and of tissues destroyed, whilst in the most dangerous forms of sepsis the local disturbance in the wound may be almost unnoticeable, and everything depends on the nature of the germs. The gravest forms may also run their course without any marked rise of temperature, and clinical experience must then found a fatal prognosis on nothing more than an abnormally hard or very compressible pulse, and the general condition of the patient.

Patients suffering from infected wounds are generally depressed or have at least a feeling of malaise; in severe cases they often become unconscious. But it is important to remember that cases of the most severe forms of septic infection are often remarkable for an abnormal appearance of health, and these cases, to the astonishment of the laity, often terminate fatally in a few hours.

CHAPTER XVI.

The Improvisation of Aseptic Dressings for Emergencies and the Treatment of Injuries.

The examination of fresh wounds with fingers and probes is objectionable—So too is bathing with water—The staunching of hæmorrhage—The dressing—Sealed dressings for small wounds—Gunshot wounds and compound fractures—Extensive wounds—Improvisation.

One of the most deplorable relics of bygone times is the examination of wounds with fingers and probes. In no point do the old and new doctrines stand more directly opposed than in the carrying out of these prying examinations. Formerly the injury itself was held to be the only danger, the accurate knowledge of its extent, the determination of its depth and breadth, feeling after splinters of bone appeared as an important duty, the very ground and foundation of rational therapeutics. Now-a-days the danger of an open wound is seen to depend upon its infection, and all our efforts are directed to preventing the fungi which bring about this infection from reaching the wound. The orderly course taken by the healing of even enormous subcutaneous injuries, might have convinced the surgeons of the past of what we daily see confirmed by the behaviour of wounds under aseptic dressings. The most extensive wounds of bones and soft parts heal rapidly, whether lacerated or crushed, provided only that no germs of infection take up their abode in the wound. All probing of a fresh wound with fingers or instruments, by which

germs can be conveyed to its depths, must be carefully avoided.

Another old and widely prevalent custom in the treatment of injuries, which must be fought against, is that of washing out wounds with water. This is so deeply rooted, that by many it is held as a first principle that all wounds should be thoroughly washed out before any other treatment is undertaken; water, from the nearest puddle, or anywhere, rather than not at all, is sluiced over it with a serene disregard for the germs it may contain, and a blind confidence in its cleansing powers. And all the while nature is making efforts on her part with what could hardly be improved upon, a stream of blood free from any kind of germ, springing from every corner and crevice of the wound. What protective plaster again can be devised better than the pure freshly coagulated blood. We should do well to reserve our irrigations for cases of an exceptional nature, when mud or obvious filth is present, and even then use, not the first water that comes to hand, but only such as we know to be free from pathogenic germs.

Lastly, our interference may be called for to staunch bleeding; and here the practice of drenching wounds with so-called styptics, astringent and caustic substances, such as vinegar, perchloride of iron, &c., is one that must be specially indicted.

While by these means we succeed in damaging the tissues, contaminating the surfaces of the wound, and placing difficulties in the way of healing, we entirely fail in our object of quickly thrombosing any of the larger vessels. In the great majority of cases, simple compression of the wound is all that is required, and this is effected by a dressing and a firm bandage. The rarer accident of a wound of one of the larger arteries

is best met by the application of an india-rubber tube, or a rope firmly secured round the limb. Cases in which the immediate ligation of the larger vessels is advisable certainly belong to the rarities of daily practice. Even an energetic compression and constriction of a limb can be maintained for two or three hours without injury, and it will be almost always possible in this time to put the patient under such conditions as will enable the dressing to be carried out under the proper aseptic precautions.

An emergency dressing usually has to consist of nothing but a few layers of some dry dressing which is free from germs, bandaged over the wound, and a splint by which the injured limb is set at rest. Iodoform gauze or simple sterilized gauze is best suited for a provisional dressing. When these are not at hand, some other material must be chosen which is, or can be, rendered free from germs. Only as a last resource should we entertain the idea of using cotton-wool, which is still too often the first material thought of for the immediate treatment of a wound. Nothing is less suitable; it sticks fast to the surfaces of the wound, and when the dressing is taken off, particles always remain behind, and delay the ultimate healing. We ought to remember that freshly washed and ironed linen usually contains only very few germs and is often still the best substitute for sterilized gauze. If no materials are at our disposal but those of which we must be suspicious, the dressing may be dipped for from ten to twenty minutes in 1 in 1000 solution of sublimate, or better still be boiled for a few minutes in water and then squeezed out and allowed to cool.

It is hardly possible to lay down definite rules for the treatment of all kinds of injuries; because each case

will have special circumstances of its own. But one great distinction should in the light of modern ideas be always borne in mind; the case of an extensive wound differs very greatly from that of a smaller one. The prognosis in the latter case as far as it concerns the chance of wound-infection, is remarkably favourable, if only the subcutaneous character of the wound is preserved, and if the treatment is confined to covering it with some simple dressing after a thorough disinfection of the skin in its vicinity (Chapter V.). These remarks apply to all compound fractures with small skin wounds, and above all to the gunshot wounds inflicted by modern small bore firearms. The first expression of these views was the result of the military experience of von Volkmann in the wars of 1866 and 1870. At the congress of German surgeons in 1872, he publicly announced as the result of his experience that all these injuries progress most favourably, if extensive surgical proceedings, slitting up, draining, &c., are refrained from, and if a simple sealed dressing is put on and the wound subsequently treated as subcutaneous. It was the simple aseptic sealed dressing that gave von Bergmann and his assistant Reyher such brilliant results in the Russo-Turkish war. It cannot be denied that when a fractured bone pierces the skin, even if one snips off the projecting end of bone, or in a bullet wound, pathogenic micro-organisms may have penetrated to the deeper parts: but the fact remains that an unfavourable result is very rarely seen under a sealed dressing, that these injuries almost always take a non-inflammatory course and that the projectile heals in without causing any trouble. In a city with a population of over a million, bullet wounds and compound fractures are by no means rare, and yet in von Bergmann's Clinic there is no case

on record in which a simple bullet wound, or a fracture with a small wound has not healed in a short time and without complication, under the aseptic sealed dressing. In the battle of Gorni Dubnik in the Russo-Turkish war, von Bergmann selected from a number of bullet wounds of the knee, fifteen of the most severe, in which besides the opening of the knee joint the bone was much comminuted, and treated them with sealed dressings. In each case after thorough disinfection of the surrounding skin, a salicylic gauze dressing was used and a plaster of Paris splint was put on to fix the parts. They all healed with a single exception, and that in spite of the fact that the wounded had to be transported through the Steppes for days together in pouring rain and over softened roads; and that this injury of the knee joint is one of those which formerly gave the most melancholy results in military practice, the mortality, as calculated by Reyher for the old treatment of probing and non-aseptic dressings, standing as high as 95 per cent.

In the treatment of injuries with extensive wounds great judgment and experience are required in order to make the conditions as favourable as possible. Much can now-a-days be done by the extensive use of the tamponade of iodoform gauze, and by it many a limb is now saved which even in the beginning of the antiseptic era would have been sacrificed to the amputating knife. Large wounds often complicated with extensive crushing of the soft parts, and tearing away of the skin, are prepared for the tamponade according to the principles which we have laid down in a preceding chapter for the treatment of large operation wounds. The irrigations of sublimate or carbolic solutions, formerly so much in favour, should here again be avoided as far as

possible, and should be replaced by sponging with sterilized gauze.

Our guiding principle must always be to undertake no operative procedures of any kind, and to interfere as little as possible, when the aids of asepsis are not at hand. The orders for the first aid to the wounded on the battle field are rightly limited to simply covering the wound and placing the limb in a suitable position. Anything more than this must be left for the stationary and field hospitals. The surgeon who is called to a wounded patient has, as a rule, simply to preserve the wound from all unnecessary and meddlesome manipulations, and to despatch the patient with a simple sealed aseptic dressing to the nearest hospital.

In the great majority of cases that is all that is required, immediate operation can only be called for under the most exceptional conditions; but even then aseptic treatment in the hands of those who understand it, shews its greatness and celebrates its greatest triumph in the simple and unassuming methods which it affects. Fire, water, and some means of boiling it being given, the true surgeon, and one who has imbibed the true spirit of asepsis, will be at once at home and will improvise everything else. Boiling water provides him sterilized instruments, sterilized thread or silk for ligature or suturing, and sterilized though wet dressings made from boiled linen compresses squeezed out. In this way it is conceivable that a surgeon, miles away from any civilization, should carry out an amputation, the ligature of some great vessel, or an urgent herniotomy, with a result it may be not inferior to that attained on the marble floor of a modern operating theatre.

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CHAPTER I.

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CHAPTER II.

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For further details, especially with regard to the old Literature, *see* PETRI'S contribution.

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